ALLIS-CHALMERS

ELECTRICAL REVIEW

December • 1940

During assembly for alignment, a section of the speed ring for a 55,000 hp propeller type hydraulic turbine is lowered into place.

WHY SWITCHGEAR SAFETY MEANS *Switchgear Savings!*

Check These Three Ways Allis-Chalmers Vertical Lift Metal-Clad Switchgear Can Cut Your Maintenance and Operating Costs . . . Give You Added Safety for Your Equipment and Your Workers!

With Modern Allis-Chalmers Metal-Clad . . .	YOU GET EXTRA SAFETY!	YOU GET EXTRA SAVINGS!
Shipped completely assembled! 1	Allis-Chalmers Metal-Clad is shipped in groups of five to ten units...factory tested. You don't have to worry about faulty connections . . . incorrect wiring.	Your installation costs are cut. There's no need for special vaults or switching structures. Just connect the leads and you're on the way to low-cost protection.
100% Metal-Enclosed! 2	Buses, current transformers, potential transformers, circuit breakers and secondary parts for control are all enclosed in individual compartments. Your workers get complete protection from live parts.	Dust and dirt can't get inside. Complete metal enclosure keeps them out... adds years of life to your equipment.
Built with "QUICK-QUENCH" Ruptor-equipped Breakers! 3	The fast, positive action of husky breakers means added protection for your equipment . . . the possible quick reclosing added protection for your customer good-will.	Arcs are snuffed out in split cycles by the famous "QUICK-QUENCH" action of Ruptors. Oil carbonization and contact deterioration are held to a minimum . . . oil throw eliminated. A 1220

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1 Does it save on floor space?	NO	YES	As much as 50%.
2 Does it take a lot of head room?	YES	NO	Sometimes ¾ amount for older type.
3 Is its appearance attractive enough to harmonize with the rest of the station interior?	NO	YES	And you can select color to match station interior.
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5 Is there a complicated wiring diagram to follow during installation?	YES	NO	They're shipped completely wired.
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8 Are maintenance costs kept to an absolute minimum?	NO	YES	Complete metal-enclosure keeps dust, dirt out.

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Vol. V . . . . No. 4

December, 1940

Allis-Chalmers

Electrical Review

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Issued quarterly. Subscription rates: U. S., Mexico and Canada, $2.00 per year; other countries, $3.00. Address Allis-Chalmers Electrical Review, Milwaukee, Wisconsin.

Printed in U. S. A.
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ELECTRICAL REVIEW

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"BIG RED"

W. B. Hibbard, **Assistant Metallurgist**

AMERICAN BRASS COMPANY • WATERBURY, CONNECTICUT

That's copper . . . and its uses in modern industry are more varied than the 5,000 years during which it has played a vital roll in the progress of civilization.

● The earliest records which definitely establish the working of copper indicate that Egyptian coppersmiths made pipe in 2750 B. C. A length of this original pipe is now exhibited in the Museum in Berlin.

The Chinese were known to have worked copper and bronzes before 2500 B. C. These are the earliest written records, but how much earlier copper was worked, in both Egypt and China, is unknown.

Copper was used by the Indians before this continent was discovered. This was native copper from northern Michigan. It was not until 1846 that these copper deposits were exploited commercially. Our domestic copper industry was developed from this small beginning. Large copper deposits were later found and developed in Montana, Arizona, Utah, and Nevada; while smaller developments have been made in New Mexico, California, Tennessee, Colorado, Idaho, and Alaska.

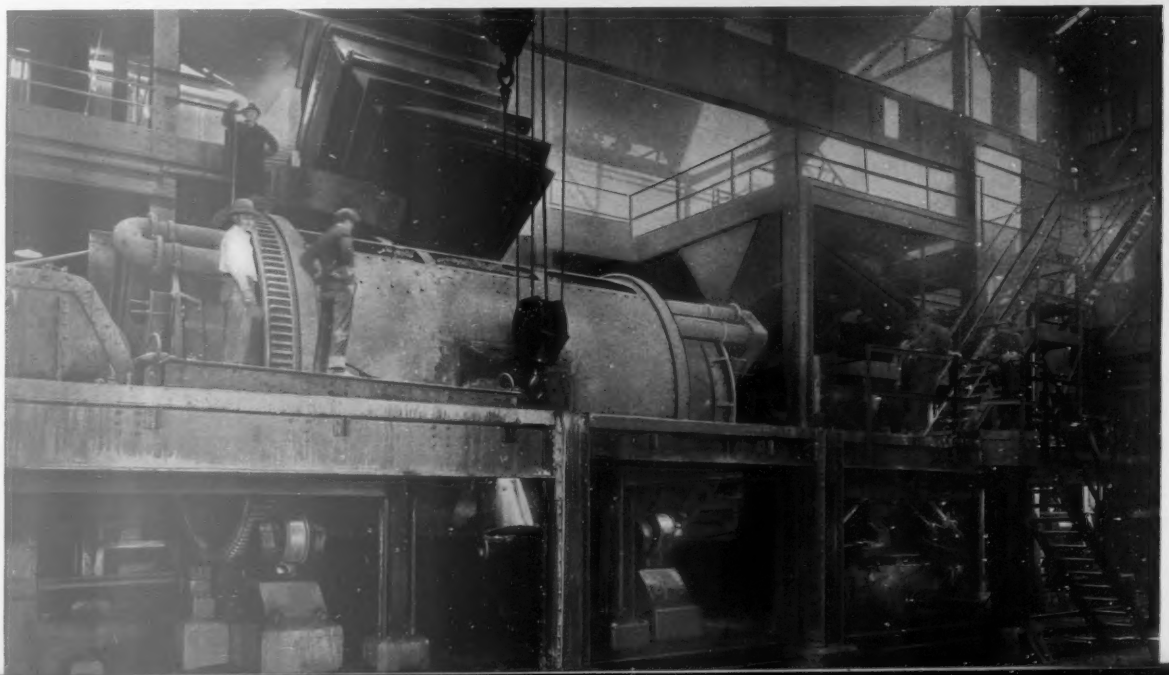
The average amount of copper in igneous rocks of the world is estimated at 0.010 percent. United States ores average about 1.4 percent copper. It occurs uncombined as native copper and in chemical combination as sulphides, oxides, silicates, chlorides, and sulphates. There are many combinations of these compounds to make the various ores, the sulphite ores being the most important.

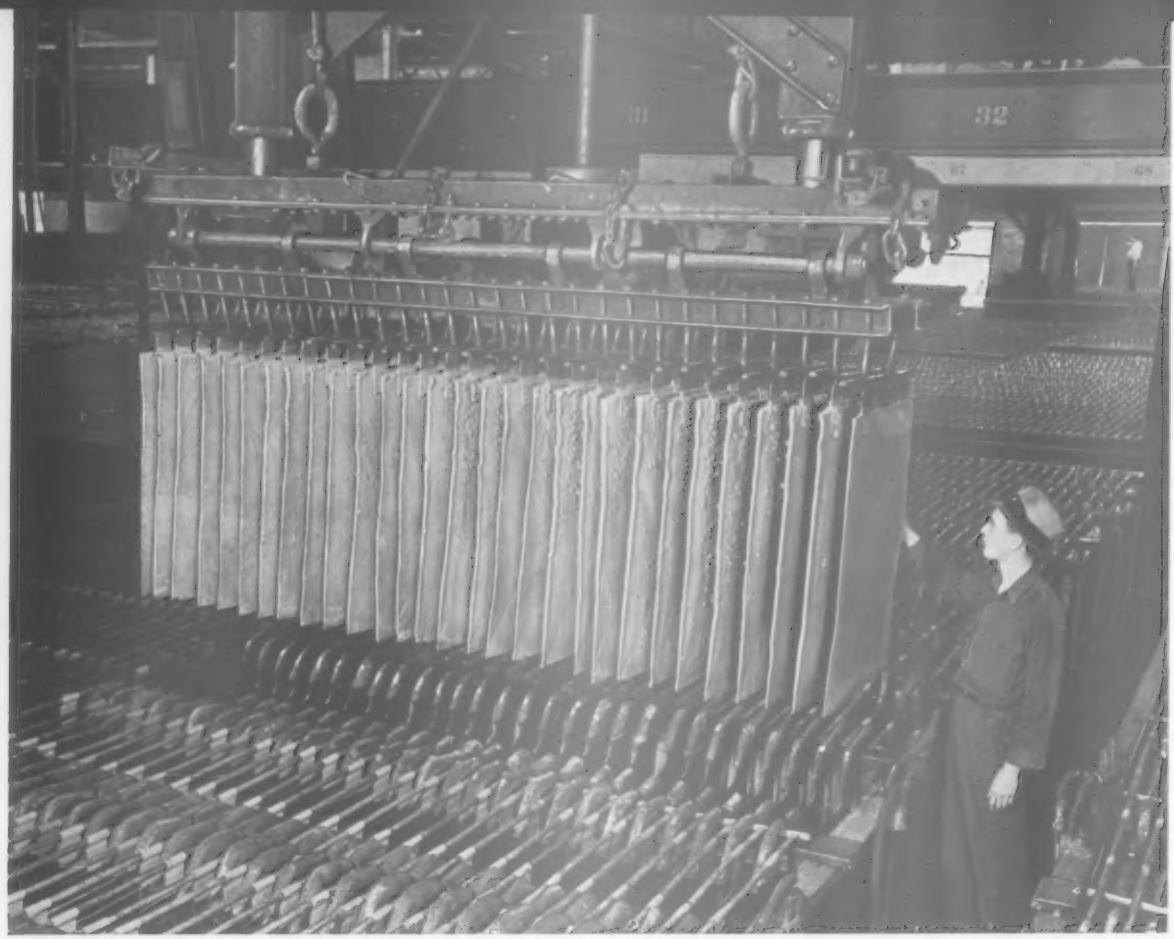
Methods of recovery

There are two classifications of ore which determine the recovery method. Hydro-metallurgy is usually

AT LEFT: Not an anti-aircraft gunner, but a miner drilling hole for the charge in a copper mine.

BELOW: Pouring 99.9 percent pure blister copper from a large converter in a Nevada conversion plant.





Cast into cathodes in electrolytic refining, this copper is about to be charged into the furnace.

used for non-sulphide ores and pyrometallurgy for the sulphide ores. The first three steps, i. e. mining, crushing, and concentrating, are essentially similar for ores of both classifications.

These ores are mined by underground or surface methods. The modern trend is toward open pit mining; and, generally speaking, these types of mines are the low cost copper producers.

The modern crushing and concentration plant tends toward finer crushing and the use of flotation, wherever possible, to concentrate the ore. The flow sheet, showing the complete process, depends upon the type of ore, grinding, equipment, etc. Often, roasting is no longer necessary, so that the concentrate is sent directly to the reverberatory furnace without drying. Flotation usually recovers about 90 percent of the copper as a 25 percent to 50 percent concentrate.

Smelting changes the copper concentrate to matte and involves a heat treatment which brings about chemical changes and melting. The resulting matte contains 21 percent to 45 percent copper. The converter then changes the matte to blister copper, which is approximately 99.9 percent pure. Converter practice varies according to the type of ore and the previous processing of that ore.

The blister copper is either fire-refined, and/or electrolytically deposited. If fire-refined, it is charged into a furnace, melted, oxidized to remove sulphur and other impurities, and reduced to about 0.03 percent oxygen. It is then cast on a wheel into the shapes required by the trade.

Electrolytic process

If the metal contains precious metals which are an advantage to recover, the blister copper goes to the electrolytic refinery after being cast into anodes. The electrical setup in the tank house may be multiple; i. e., tanks in series with electrodes in parallel, or the tanks and electrodes may be completely in series. Copper of 99.98 percent purity is deposited on the cathodes. These are removed from the tanks, washed, and rinsed thoroughly so that, for certain alloying in the brass industry, the cathodes may be used for melting.

For various copper shapes, the cathodes are charged into a furnace, blown and poled to approximately 0.03

percent oxygen, and cast on a wheel into wire bars, cakes, ingots, slabs, ingot bars, and billets.

All domestic copper is produced to standard A. S. T. M. specifications.

Electrolytic copper, as its name infers, is produced by electrolysis from fire-refined anodes, or from solution containing copper leached directly from ore. About 23 percent of the cathodes deposited are used for alloying, while the remainder are remelted and cast into shapes desired by the industry. The bulk of high conductivity copper for the electrical industry is made from electrolytic copper.

Lake copper is recovered from ores of the Lake Superior region. It differs from electrolytic copper in that it may contain small amounts of silver or arsenic.

Removal of oxygen

Deoxidized copper is made by adding a strong deoxidizing agent, such as phosphorus, silicon, or manganese, to molten tough copper to remove the residual oxygen. The usual deoxidizers lower the electrical conductivity of copper. Special high conductivity deoxidized coppers are made by using calcium, lithium, boron, or calcium boride as a deoxidizing agent.

Copper condenser tubing is produced by the hot extrusion process.

Oxygen-free copper is produced by casting copper under conditions that do not permit oxygen to be absorbed. Its conductivity is equal to electrolytic copper, and it meets the standard A. S. T. M. specifications. One commercial process for producing this type of copper is to compress broken cathodes in a reducing atmosphere when hot and then extrude the copper into bars or shapes as required.

The oxygen-free copper will stand heating in hydrogen atmosphere for one hour at 850 C and will stand a reasonable number of bends after such an anneal.

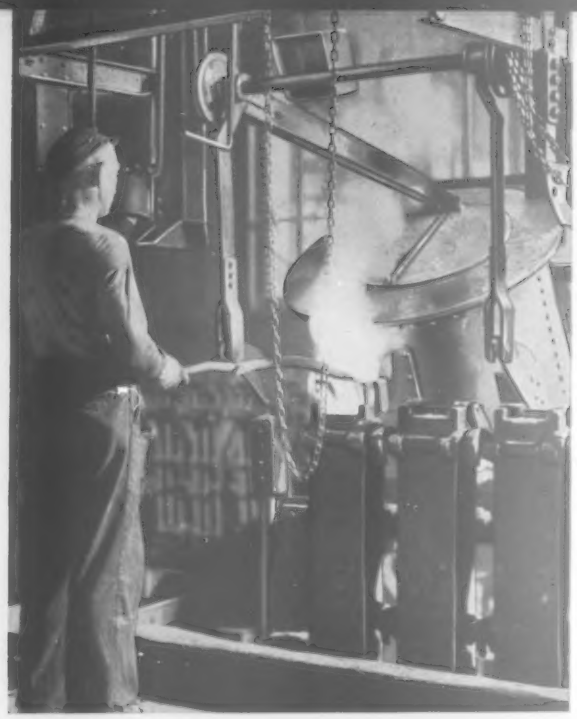
If copper containing oxygen (tough pitch) is heated in a reducing atmosphere at a temperature above 400 C, it becomes severely embrittled. It is known in the trade as "gassed copper" and is of no commercial value.

Rolling and shaping

Copper is malleable at any temperature below 1050 C. Hot rolling usually starts at 850 C and may be continued as low as 400 C. For hot extrusion or hot piercing, the temperature is more critical, and in all cases the muffle must have a neutral or slightly oxidizing atmosphere to avoid "gassing" the product.

Copper is seldom used in the hot rolled condition but is cold rolled and annealed or cold rolled, depending upon the use to which it is to be put. It is worked into wire which meets A. S. T. M. standard specifica-

AT LEFT: Drawing copper wire through multiple tandem dies.



tions, and into rods, bars, sheets, plates, strip, and shapes to Federal specification QQ-C-501. These specifications have requirements for electrical conductivity which are easily met with commercial material.

Copper and its alloys are worked and fabricated by the usual metal working methods, such as rolling, drawing, stamping, extruding, spinning, casting, forging, and welding. It is generally used where its resistance to corroding agents is an advantage or where electrical or heat conductivity is desired.

Copper is alloyed or mixed with zinc, tin, nickel, cobalt, silicon, aluminum, manganese, iron, beryllium, cadmium, chromium, and lead. The alloys can be worked to give varying properties, depending upon the intended use.

AT LEFT: In the form of one of its alloys, copper here is poured for brass bars in a wire furnace.

According to the American Bureau of Metal Statistics, the use of copper and copper alloys in the United States is shown in the following table.

Estimated ultimate uses of copper in short tons

	1930	1931	1932	1933	1934	1935	1936	1937	1938
Electrical manufacturers[1] ..	221,000	162,000	90,000	90,000	101,000	128,000	164,000	212,000	150,000
Telephones and Telegraphs.	122,000	70,000	27,000	18,000	18,000	18,000	26,000	40,000	30,000
Light and Power Lines[2]...	130,000	85,000	49,000	33,000	36,000	55,500	72,000	83,000	62,000
Wire and Wire Cloth.....	102,900	59,900	34,200	51,000	44,600	53,600	96,500	108,800	66,000
Ammunition	5,100	5,000	3,900	10,500	13,500	13,700	11,900	14,100	12,500
Automobiles[3]	87,000	61,600	32,300	49,000	63,000	95,000	108,000	112,000	55,000
Buildings[4]	50,000	45,000	29,000	36,000	36,000	49,000	71,000	70,500	67,500
Castings, n. e. s.[5]	55,400	36,000	27,000	36,000	36,000	36,000	39,000	40,000	31,000
Clocks and Watches	2,600	2,000	1,500	2,800	2,200	2,400	3,400	4,000	3,000
Copper-bearing Steel	1,900	1,200	800	1,500	2,100	2,300	3,900	4,600	2,600
Radiators, heating	3,000	1,700	1,000	2,400	1,000	1,100	2,000	2,100	2,000
Radio Receiving Sets	13,000	10,000	7,000	11,500	12,500	16,000	24,000	23,100	17,500
Railway equipment	8,600	1,300	700	800	2,100	1,800	4,000	7,100	1,700
Refrigerators, automatic[4] ..	15,000	13,000	9,000	11,400	15,700	15,400	15,000	13,500	6,700
Shipbuilding[4]	5,000	3,200	2,100	1,800	3,200	1,100	5,000	6,400	6,000
Air Conditioning[4(a)]	.....	.....	.....	.....	3,800	4,800	6,400	7,200	6,100
Other uses	62,550	44,400	30,900	43,700	46,800	51,500	65,300	66,600	46,200
Manufactures for export ...	71,100	48,200	22,600	15,600	25,500	29,500	31,600	45,000	39,200
Totals	956,150	650,000	368,000	415,000	463,000	574,700	749,000	860,000	605,000

[1] Generators, motors, electric locomotives, switchboards, light bulbs, etc. [2] Transmission, distribution wire, bus bars (public utilities only). [3] Starter, generator, and ignition equipment excluded. [4] Electrical equipment excluded. [a] Other than railway. [5] Bearings, bushings, lubricators, valves, fittings.

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FIRST LINE OF DEFENSE

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While blitzkrieg (lightning war) may be new in military campaigns, transformer manufacturers have long had to fight it. Chief defense is a ten year old weapon — impulse testing. Here's why it spells defeat for lightning.

● Natural lightning is a violent demonstration that man is not master over Nature's power, and it is this devastating force that an electrical transmission system must accommodate if continuity of service is to be assured. The early attempts to control this destructive force were made with crude devices, largely because of the meager knowledge concerning lightning's behavior. The irregular occurrence of lightning discharges, together with the absence of any forewarning, have made the study of lightning phenomena difficult.

Although impulse testing of electrical equipment is new, commercially available for only 10 years, its strides have been rapid. Some years after the introduction of the cathode-ray oscillograph into the physics research laboratories, enterprising engineers realized this tool possessed tremendous possibilities in the study of lightning phenomena. Around the cathode-ray oscillograph these engineers set up complex electric circuits and, after many disappointments, succeeded in obtaining permanent records of some of the characteristics of lightning discharges.

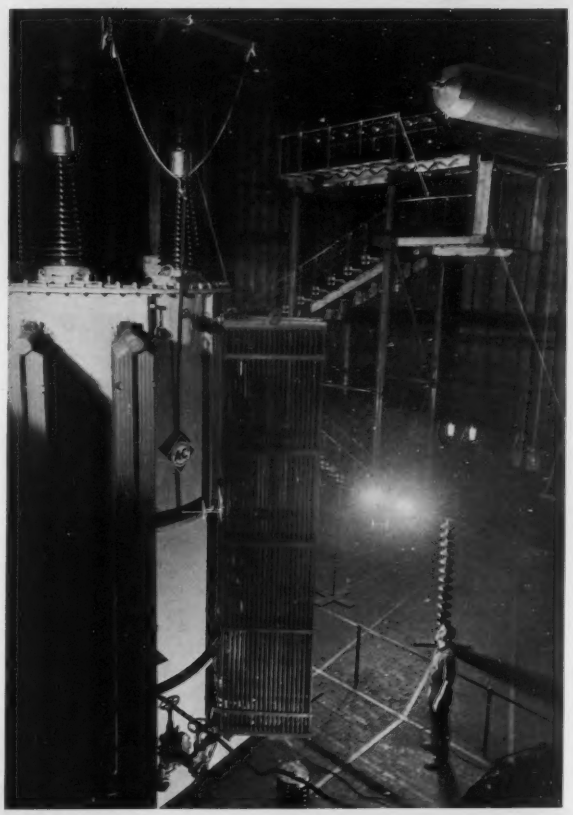
Though few in number, the available permanent records were used as a guide for further activity. Several methods of generating an artificial lightning stroke were developed. The so-called impulse or surge generator has become an important piece of apparatus in studying lightning and its effects upon transformers as well as a great variety of other equipment and materials.

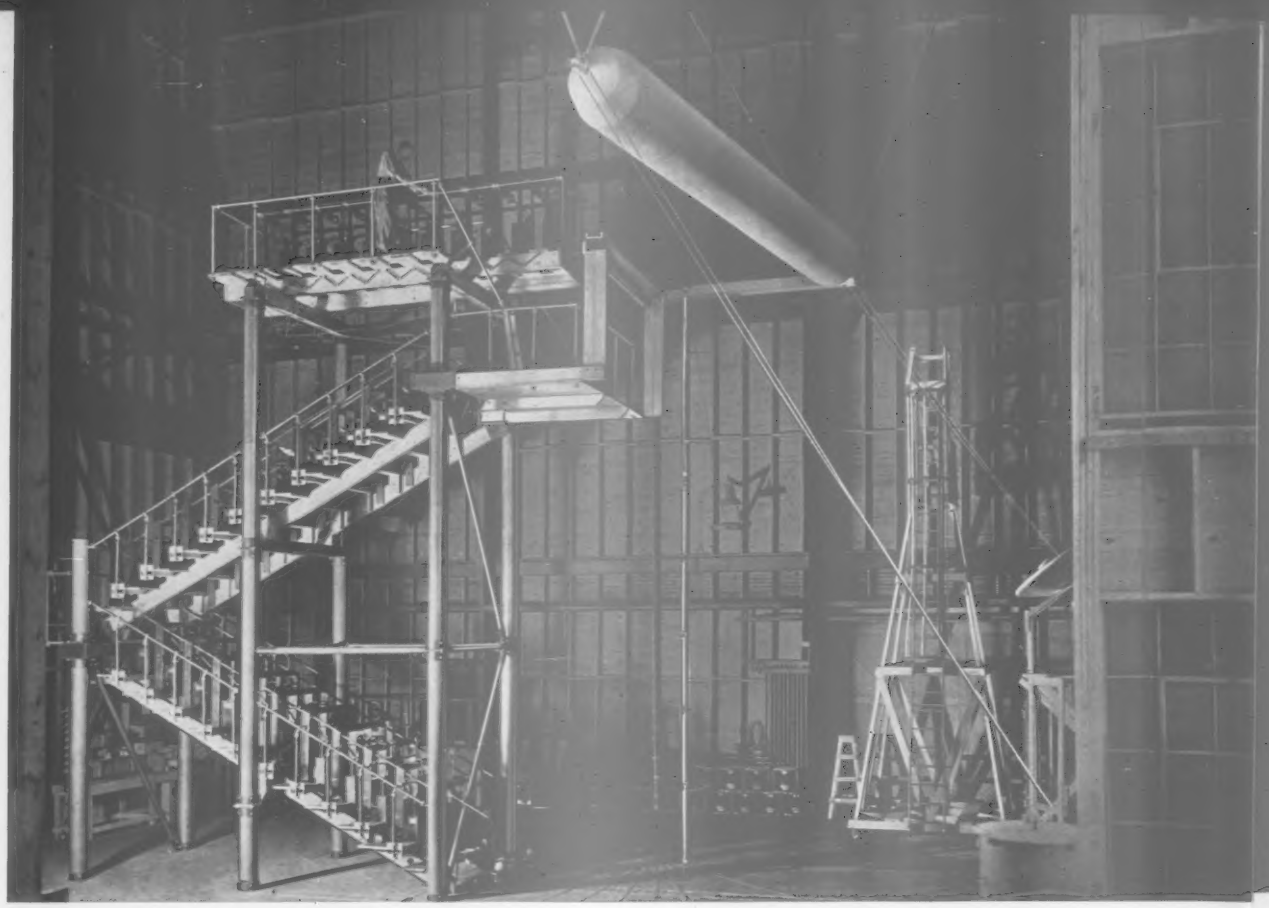
Why an impulse test

Not all abnormal overvoltages to which transformers are subjected are caused by lightning. System disturbances such as switching surges and arcing grounds introduce voltage transients that behave in a manner similar to transients caused by a lightning discharge. Because of their similarity, these overvoltages can be studied with the same equipment.

The purpose of making impulse tests on a transformer, from the user's viewpoint, is to demonstrate that the transformer has met the guaranteed requirements of impulse strength. From the manufacturer's

BELOW: Impulse wave chopped by a rod gap with power follow during the testing of a 20,000 kva power transformer.





This 3,000,000 volt impulse generator is used to test large power transformers. Smaller units are tested on a 1,000,000 volt generator of similar construction.

standpoint, impulse tests furnish a check on the design of a transformer, a widening of his knowledge of lightning phenomena, and a determination of the strength of construction materials — all leading toward the development of a better transformer.

Testing facilities necessary

In addition to the generator, impulse testing equipment consists of such items as the discharge circuit, the cathode-ray oscillograph, and the voltage divider. Factors that must be taken into consideration are the capacitance and inductance of the transformer under test, the length of circuits from the generator to the transformer, the connection of the voltage divider to the cathode-ray oscillograph, the length of the main discharge circuit, and the effectiveness of the grounds, as well as electromagnetic and electrostatic interference.

In addition, the equipment necessary to produce and record the waves is generally augmented by a source of power for exciting the transformer under test, a device for synchronizing the impulse wave with the crest of the alternating voltage wave, a test gap, and means for limiting the power-follow current across the gap.

There is great variety in the impulse generating equipment found in the various laboratories. Each laboratory has its particular practices; but, however different in detail, almost all present-day impulse generators utilize the Marx circuit as a basis of design. The dissimilarity between laboratories is in the physical arrangement and construction of the generator and in the measuring and control circuits.

Basic Marx circuit used

The basic Marx impulse generator circuit is shown in Fig. 1. This circuit can be analyzed as two superimposed circuits — the charging circuit, Fig. 2, and the discharge circuit, Fig. 3. The condensers are charged in parallel from a high voltage rectifier. The discharge circuit is arranged to give an accumulative voltage equal to the sum of all the individual condenser voltages. The polarity of the discharge is changed by reversing the connections to the rectifier, and a variable charging voltage for incremental changes of generator output voltage is available.

One method of initiating the generator discharge is to introduce an impulse voltage from a more easily controlled auxiliary source to the center electrode of the multiple gap connected between the first and second steps of the condensers, Fig. 1. The flashover of the series gaps is progressive although for most purposes it is considered simultaneous. Almost all voltages in surge testing are measured with respect to ground potential.

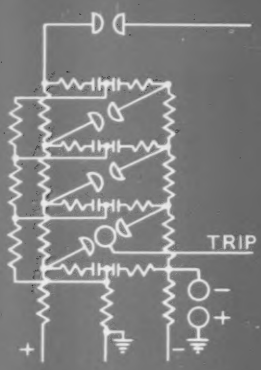


Fig. 1

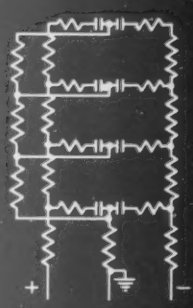


Fig. 2

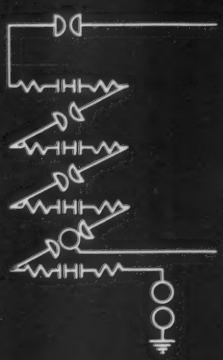


Fig. 3

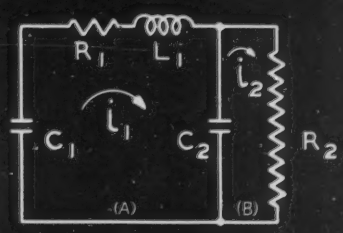


Fig. 4

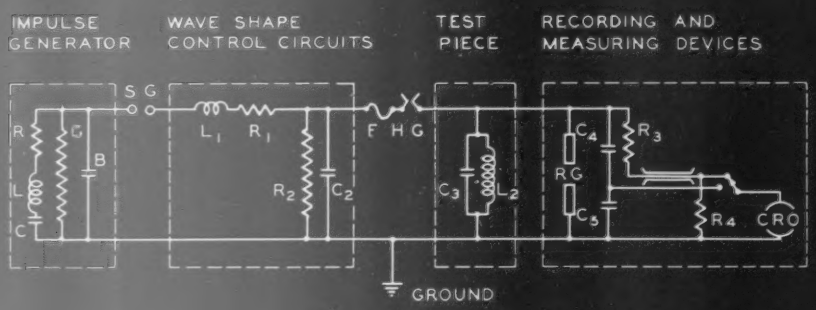


Fig. 5

C = generator capacitor units, charged in parallel and discharged in series.
L_1 = inherent inductance in generator circuit.
R = inherent resistance in generator circuit.
G = leakage conductance of charging resistors and generator frame.
B = susceptance due to terminal capacitance of gaps, leads, etc.
L_1 = inductance to retard wave front or to control oscillations.
R_1 = resistance to control front of wave and reduce oscillations.
R_2 = resistance to control duration of wave.
C_2 = capacitance to retard front or to control oscillations.
C_3 = effective capacitance of test piece.
L_3 = effective inductance of test piece.
C_4 and C_5 = capacitance potential divider.
R_3 and R_4 = resistance potential divider.
Z = surge impedance of divider cable.
R_4 = Z to prevent reflections.
CRO = cathode-ray oscillograph.
SG = sphere gap.
F = fuse.
HG = horn gap.
RG = rod gap (standard test gap).

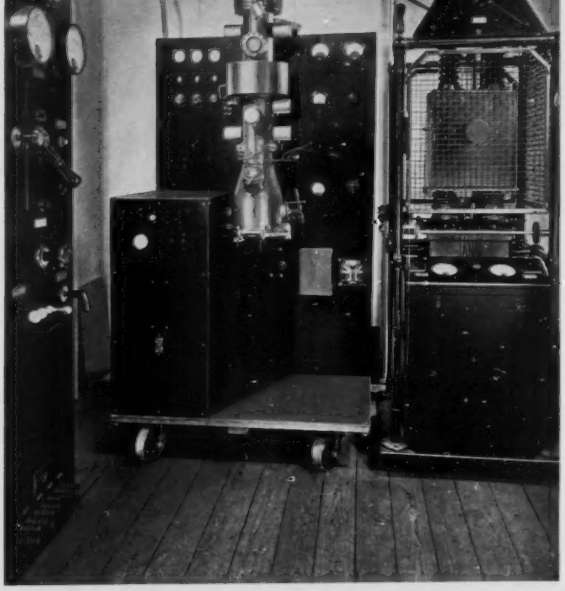
The equivalent circuit of the generator of Fig. 3, together with the wave shape control circuits, measuring circuits, and a typical load are shown in Fig. 5. When this circuit is modified to accommodate practrical laboratory flexibility, it becomes Fig. 4. Such components as L and L_1 of Fig. 5 are referred to collectively as L_1 in Fig. 4. Similarly, R and R_1 are lumped into R_1; G, R_2, and R_3 into R_2; and B, C_2, and the equivalent of C_4 and C_5 in series into C_2 in Fig. 4.

The front of the impulse wave is controlled by changing any one or a combination of R_1, L_1, and C_2. One effect of an increase in any one of these is to slow the rate of voltage rise appearing across R_2 and C_2 at a sacrifice in output voltage. An increase of R_1 reduces the magnitude of oscillations, the source of which may be C_1 or C_2, or both, oscillating with L_1. The duration of the wave tail is controlled by R_2; an increase of R_2 lengthens the tail. When the resistance potential divider is used, the combination of R_2 and the divider resistance controls the duration. A brief mathematical analysis of the simplified circuit, Fig. 4, is given in Appendix I.

The cathode-ray oscillograph

Permanent records of the transients are obtained with the cathode-ray oscillograph, which may be considered as an "electric pencil" of infinitesimal mass. It is the only recording instrument of sufficient speed to

BELOW: Control room in the 3,000,000 volt high voltage laboratory includes (left to right) generator power panel, cathode ray oscillograph and its associated circuits, and 60,000 volt rectifier.



record these extremely high speed transients. It consists of a special type of vacuum tube with its associated control circuits. Electrons are emitted from a cathode within the tube and are concentrated into a beam that impinges upon a screen. The impact of the electron beam causes the screen to fluoresce. A trace is drawn when the beam is placed under the influence of an electric field or magnetic field, or a combination of both. This luminous trace may be recorded photographically; however, the recording efficiency may be greatly increased by allowing the electron beam to impinge directly onto a photo-sensitive emulsion. The latter method is used extensively.

Basic voltage deflection characteristics of the cathode-ray oscillograph for calibration purposes are made by the application of a d-c voltage of the proper polarity to the oscillograph deflection plates. All time measurements are made with a high frequency oscillator which generates an accurately pre-determined frequency. Frequencies commonly used are 50, 100, 500, 1000, 5000, and 10,000 kilocycles per second, all in the radio frequency spectrum.

The test wave

Early investigation of the characteristics of natural lightning gave rise to a convenient voltage test wave, now a generally recommended American practice, the shape of which is defined by the expression "1½x40." This means the voltage rises from zero to its crest in 1½ microseconds and diminishes to one-half its crest value in 40 microseconds.

A great variety of wave shapes will meet the requirements for a 1½ microsecond front, and for standardization purposes a "10 and 90 percent rule" has been established. This rule is illustrated in Fig. 6. The virtual time zero, O_1, Fig. 6, is determined by locating points on the front of the wave at which the voltage is 10 and 90 percent, respectively, of the actual crest value and then drawing a straight line through these points.(1) The intersection of this line with the time axis (zero voltage line) is the virtual time zero. If oscillations are superimposed on the front of the wave, the 10 and 90 percent points are determined from the average smooth wave front sketched in over the oscillations. The wave should be as smooth as possible since oscillations have the effect of increasing the stress on a transformer winding under test.

The standard 1½x40 microsecond wave is one for which O_1X_1, Fig. 6, is 1.5 microseconds and O_1X_4 is 40 microseconds. If the actual crest is difficult to determine, it has been proposed that, for transformers, the virtual time-to-crest be defined as the interval between the 0.1E and 0.9E points on the wave front times 1.5, in which case the virtual time-to-crest is 1.5 (X_2-X_3).

Variations from standard

The difficulties confronted in testing different specimens necessitate variations from the standard wave in the interests of a practical testing technique. The accepted tolerance at present is ± 1.0 microsecond on the wave front and $^{+10}_{-0}$ microseconds on the wave tail; but, as rapid strides are being made in the technique of this new field, it is probable that the present tolerance for the time-to-crest may be decreased.(2)

The load of a string of suspension insulators is capacitive and the capacity is quite low. A transformer, on the other hand, presents an entirely different load on the impulse generator. The load of Fig. 7 is an equivalent circuit corresponding to a transformer, taking into consideration mutual coupling between the primary and secondary windings. In Fig. 8 this load is represented in a manner more convenient for circuit analysis. A transformer load on the impulse generator consists of capacity and inductance in parallel. The series resistance of the winding under test is generally negligible. Initially the transformer dielectric capacity controls the behavior of the transient voltage; but, as time passes, surge current flows through the winding to ground, and the transformer inductance exerts its influence on the test wave.

The parameters of the surge generator are adjusted to give the specified wave shape with the transformer connected. After these adjustments are completed, changes in the test voltage can be made by varying the charging voltage applied to the generator. Should the voltage applied to the transformer be changed by changing the circuit parameters, it is again necessary to demonstrate the wave shape and magnitude of voltage for the changed conditions.

The magnitude or crest of the voltage wave applied is governed by the voltage class for which the transformer is insulated. Impulse test voltages have been standardized for each transformer voltage class. Originally these voltages were specified in terms of rod gap distances, but such voltage measuring methods are affected by the homogeneity of the field of the gap, barometric pressure, vapor pressure, temperature, foreign substances in suspension in the dielectric, and solar radiations, as well as the electrostatic and electromagnetic fields produced by the geometry of the laboratory. Test voltages are now specified in terms of a minimum kilovolt crest which must be applied to the terminals of the transformer.

Testing a transformer

Impulse tests are generally applied with the transformer excited at normal voltage and the impulse wave synchronized to occur within 30 electrical degrees of the crest of the excitation voltage wave of opposite polarity from that of the impulse. A capacitance potential divider is widely used whenever impulse tests are made with normal excitation. Such a divider is represented in Fig. 5 by C_4 and C_5. An air condenser provides a practical and economical high voltage condenser of sufficiently small capacity. The

(1) A proposal to use points at 30 and 90 percent is under consideration by the interested parties. Some waves require considerable time to reach their maximum rate of rise. Here a 30 percent point is more suitable than is the 10 percent point for the front of wave determination.

(2) The EEI-NEMA subcommittee on correlation of laboratory data in AIEE Transactions Paper 40-38 recommends that the wave front tolerance be made ± 0.5 microseconds when no disruptive discharge occurs and where a particular apparatus standard involved does not specify a different tolerance. It is likely the proposed transformer standard will be changed accordingly.

AT RIGHT: Before shipment to Boulder Dam, the contact fingers of the movable portion of this 4,000 ampere, 23,000 volt, 2,500,000 kva vertical lift metal-clad switchgear are gauged for accurate spacing.

capacity potential divider is calibrated by means of the resistance potential divider. This calibration is made before the transformer is connected to the generator and may be duplicated after the transformer has been connected but before excitation is applied. The resistance potential divider is then removed from the circuit electrically and physically.

The standard impulse test applied to a transformer winding consists of two applications of a chopped wave followed by one application of a full wave. Either a positive or a negative wave may be used. The chopped wave may be obtained by flashing over either an external rod gap or the transformer bushing. The applied voltage wave should have a crest value and minimum time to flashover in accordance with the data given in Table I. The full wave test must meet a minimum crest voltage, and no flashover of the bushing or test gap shall occur.

Impulse tests are applied to one terminal at a time on most power, distribution, and instrument potential transformers. The test is applied to each line terminal of all transformers tested and to the neutral of a three-phase transformer if the neutral is brought out. The tests are usually made with one end of the winding under test and with the transformer case solidly connected to ground.

The terminals on windings or phases not being tested are shunted to ground by a gap or protected by other appropriate means. This condition applies to the neutral of any transformer designed for isolated-neutral operation and to all line terminals of an auto transformer. All transformers designed for grounded-neutral operation are tested with the neutral solidly grounded.

The term "protected by other appropriate means" generally infers that a lightning arrester of the proper voltage is connected from the line terminal to ground. All grounds are direct except where a neutral-grounding impedance is used in service. The same impedance should be used on test if available; otherwise the neutral is solidly grounded.

All single-phase transformers for grounded Y, delta, or Y-delta operation where the Y connected neutral is insulated for delta operation are tested on the Y connection with the neutral end grounded.

Series-multiple windings are tested on both series and multiple connections, and the windings not being tested are connected for the highest rated voltage during tests.

Tap connections (both transformers and auto transformers) are made with minimum turns in the winding under test and with maximum turns connected in all other windings. The secondaries of current transformers, either of the bushing type or those permanently connected to the main transformer windings, are short-circuited and grounded. If, in service, protective devices are to be permanently connected across series windings or reactors, these protective devices should be so connected during test.

Potential transformers are tested as above by applying the impulse to the polarity lead of the high voltage winding with the opposite lead grounded; then to the non-polarity lead with the polarity lead grounded; and finally with both leads connected together. In testing transformers equipped with fuses, the impulse test is applied directly to the transformer terminals, thus shunting the fuses.

Current transformers, on the other hand, are tested by applying the impulse voltage to both primary leads simultaneously, and no low frequency excitation is applied. Otherwise the tests are made the same as distribution transformer tests.

Difficulties encountered

As the transformer kva increases, it becomes more difficult to maintain the proper length of wave tail during an impulse test. This is especially true when the winding kva is large and the winding voltage is low. A low impedance load necessitates an impulse generator with greater energy availability (a larger microfarad capacity) in order to maintain the desired length of wave tail. A generator of greater capacity introduces additional complications since the percentage of generator voltage realizable at the load is greatly reduced, and any undesirable oscillations are more difficult to suppress because more energy must be dissipated.

It is, therefore, the practice to impulse test a transformer winding of very low inductance by tieing the terminals together. The transformer excitation must be omitted in this case. Occasionally, however, a condition may arise where it is not possible to tie the terminals together for the test. Then a reduced length of tail may be used, but in no case should the wave tail be shorter than 25 microseconds to the 50 percent point.

A further complication confronted in transformers of high kva and low winding voltage is the increase in the time-to-crest brought about by the large capacity to ground of the dielectric under test.

Detecting failures

A very important matter in impulse testing technique is the detection of failures. There are a number of ways by which a dielectric failure can be detected, some of which are noise within the transformer, presence of smoke or bubbles, failure of the gap or bushing to flashover when actually a sufficient surge voltage has been applied, and an indication on the cathode-ray oscillogram of foreign oscillations or other variations from the expected wave shape.

The purpose of applying normal excitation voltage during impulse tests is to provide a condition suitable for indicative power-follow current if an impulse produces a failure. However, since the beginning of commercial impulse testing, most laboratories have not yet experienced such a power-follow current. It is highly problematical whether such excitation is beneficial or whether it is an unnecessary complication to the test. The general experience is that the cathode-ray oscillogram will indicate a dielectric failure, provided the operating technique does not include measures and devices which suppress minute oscillations and deflections or introduce foreign deflections. The proper interpretation of oscillographic records is a matter of theoretical and practical analysis balanced with experience.

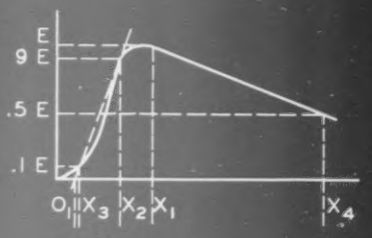


Fig. 6

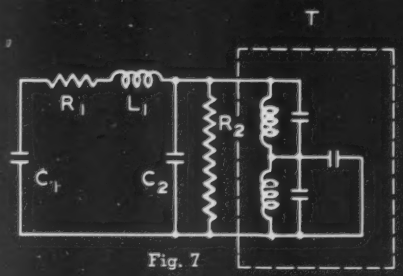


Fig. 7

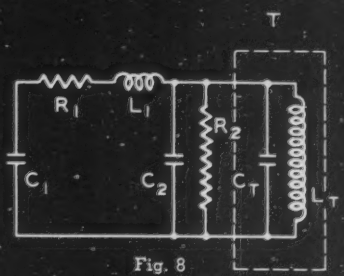


Fig. 8

Many precautions are taken to eliminate the possibility of failures in transformers from overvoltages. Numerous expensive samples of actual transformer insulation are tested to destruction. The behavior of a transformer under impulse conditions is determined from a voltage distribution test on an actual transformer assembly. The worth of new developments and changes is tested by subjection to impulse voltages.

Man may be unable to prevent Nature's display of wrath, but through science and good engineering Nature's energy may be directed to paths less susceptible to destruction.

Appendix I

A mathematical analysis of the impulse generator circuit is complex and extremely laborious if handled with ordinary differential equations. Heaviside's operational calculus simplifies these analyses. The condition in circuit (a) of Fig. 4 expressed operationally is

$$(1)\quad (R_1+R_2)\,i_1+L_1i_1p+\frac{i_1}{C_1p}-R_2i_2=E$$

and in circuit (b)

$$(2)\quad -R_2i_1+R_2i_2+\frac{i_2}{C_2p}=0$$

From equation (1)

$$(3)\quad i_1=\frac{E+R_2i_2}{R_1+R_2+L_1p+\dfrac{1}{C_1p}}=\frac{(E+R_2i_2)\,C_1p}{(R_1+R_2)\,C_1p+C_1L_1p^2+1}$$

Substituting equation (3) in equation (2) and solving for i_2

$$(4)\quad i_2=\frac{\dfrac{Ep^2}{L_1}}{p^3+\left(\dfrac{R_1}{L_1}+\dfrac{1}{R_2C_2}\right)p^2+\left(\dfrac{1}{C_1L_1}+\dfrac{R_1}{R_2C_2L_1}+\dfrac{1}{C_2L_1}\right)p+\dfrac{1}{R_2C_1C_2L_1}}$$

Expressing the denominator of equation (4) as

$$(p+\alpha)\,[(p+\lambda)^2+\omega^2]$$

and denoting

$$A=\frac{1}{C_2L_1}$$

the voltage across C_2 is

$$e=\frac{i_2}{C_2p}=\frac{AEp}{(p+\alpha)\,[(p+\lambda)^2+\omega^2]}$$

which expands into

$$(5)\quad e=\left[\frac{p}{p+\alpha}-\frac{\lambda-\alpha}{\omega}\,\frac{\omega p}{(p+\lambda)^2+\omega^2}-\frac{p^2+\lambda p}{(p+\lambda)^2+\omega^2}\right]\frac{AE}{(\lambda-\alpha)^2+\omega^2}$$

The solution of equation (5) as a function of time becomes

$$(6)\quad e=\left[\varepsilon^{-\alpha t}-\varepsilon^{-\lambda t}\left(\frac{\lambda-\alpha}{\omega}\sin\omega t+\cos\omega t\right)\right]\frac{AE}{(\lambda-\alpha)^2+\omega^2}$$

Equation (6) states that an oscillation is superimposed on the unidirectional component. $\dfrac{AE}{(\lambda-\alpha)^2+\omega^2}\,\varepsilon^{-\alpha t}$.

The oscillation is completely eliminated when $\omega^2=0$, in which case equation (6) transforms into

$$(7)\quad e=\left[\varepsilon^{-\alpha t}-\varepsilon^{-\lambda t}\left\{(\lambda-\alpha)t+1\right\}\right]\frac{AE}{(\lambda-\alpha)^2}$$

TABLE I—STANDARD INSULATION TEST LEVELS FOR TRANSFORMERS

Max. Circuit Voltage Kv*	Low Frequency Dielectric Tests Kv Rms	IMPULSE TESTS 1½x40 MICROSECOND WAVE					
		Distribution Transformers and Feeder Voltage Regulator			Power Transformers		
		Full Wave	Chopped Wave		Full Wave	Chopped Wave	
		Crest Kv	Crest Kv	Minimum Time to Flashover Microsec.	Crest Kv	Crest Kv	Minimum Time to Flashover Microsec.
1.2	10	30	36	1.0	60	69	1.5
2.5	15	50	59	1.25	..	..	..
5.0	19	60	69	1.5	76	88	1.6
8.66	26	76	88	1.6	95	110	1.8
15.0	34	95	110	1.8	112	130	2.0
25.0	51	153	180	3.0	153	180	3.0
34.5	70	195	225	3.0	195	225	3.0
46.0	93	245	290	3.0	245	290	3.0
69.0	139	345	405	3.0	345	405	3.0
92.0	185	445	515	3.0	445	515	3.0
115.0	231	540	625	3.0	540	625	3.0
138.0	277	645	750	3.0	645	750	3.0
161.0	323	750	870	3.0	750	870	3.0
196.0	393	900	1055	3.0	900	1055	3.0
230.0	461	1050	1210	3.0	1050	1210	3.0
287.5	576	1290	1495	3.0	1290	1495	3.0
345.0	691	1540	1785	3.0	1540	1785	3.0

* These values represent the maximum transformer voltage ratings normally associated with the corresponding insulation test levels.
Low frequency tests follow impulse tests when impulse tests are made.

ENGINEERING FUNDAMENTALS

Overload protection of a-c motors.

● The function of an overload relay is to disconnect the motor from the line before the motor temperature reaches an unsafe value. The heating of a motor varies as the square of the current. The curve of *time* required to reach final safe operating temperatures, plotted against percent rating in amperes, will be a hyperbola. An ideal overload relay would be one that has a time-current tripping curve parallel to and slightly below the motor curve. This ideal overload relay is not obtainable in practice, but there are several relays on the market which more or less approach the ideal, such as the magnetic, induction, and thermal overload relays which will be described in more detail.

Protecting a motor against overload is not so simple as it may first seem because of the fact that it is not usually possible to operate the protective device on a definite value of current without regard to time. In other words, two variables, time and current, are introduced in the formula for the heating of the motor. The rise in temperature is influenced by the motor design, provisions for cooling, ambient temperature, etc.

The motor starting current is usually from three to nine times the normal current and decreases rapidly as the motor accelerates. It is readily seen that a relay, properly set to protect the motor, under normal running conditions would operate on starting current if it were not provided with a time delay of several seconds. It is also desirable to permit moderate overloads to be carried for short intervals but to prevent their continuance to an extent sufficient to overheat the motor. This time delay may be provided by means of a dashpot, spring, magnetic drag on a rotating disc or heating of solder or a bimetallic ribbon.

There are three fundamental types of overload relays: the magnetic, the induction, and the thermal. These will be discussed in the order named.

Magnetic overload relay

The magnetic overload relay uses a magnet operated by a series coil carrying the motor current or, in the case of larger motors, the current transformer secondary current. The tripping value of the relay may be altered by adjusting the air gap or length of travel of the armature. A dashpot is usually used in order to provide the necessary time delay to prevent operation during starting and momentary load peaks.

Typical tripping curves for a relay of this type are shown in Fig. 1, curves A, B, and C. These curves were taken from test data on five-ampere transformer trip coils equipped with oil dashpots and illustrate the various tripping times obtainable with different dashpot valve adjustments. Relays of this type are commonly used with oil circuit breakers and provide overcurrent protection up to and including short-circuit current.

This relay may be properly termed a "Safety Valve" inasmuch as it will operate with a short time delay whenever the current reaches a predetermined value without regard to motor temperature.

Its main advantages are that it is simple, rugged, inexpensive, and resets immediately after operation. It also has an inverse time characteristic which makes it applicable for both overload and short-circuit protection. It has the disadvantage that load peaks of too short duration to operate the relay may cause overheating of the motor without disconnecting it from the line. Application is found in drives where sudden high load peaks (taking advantage of the inverse time feature) may occur; e. g., automatic punch press, conveyers, hoists, etc.

Induction overload relay

Induction overload relays are not normally used on industrial motor starters except for large motors because of the expense involved. Their construction is similar to that of a watthour-meter: A current coil tends to rotate an aluminum disc, the movement of which is retarded by permanent magnets and springs. The advantages and disadvantages are similar to those of the magnetic overload relay except that its tripping characteristics may be much more accurately predetermined. Relays of this type are frequently used for short-circuit protection on motor feeder circuits.

Thermal overload relays

The thermal overload relay is the type most frequently used on industrial motor starters because of its simplicity, low cost, small space requirements, and, most important, because its tripping characteristic more

On the erection floor — a portion of the spiral casing for one of the four Shasta Dam turbines, each rated 103,000 hp under 330 ft head.

nearly approaches the ideal than that of either the magnetic or induction types.

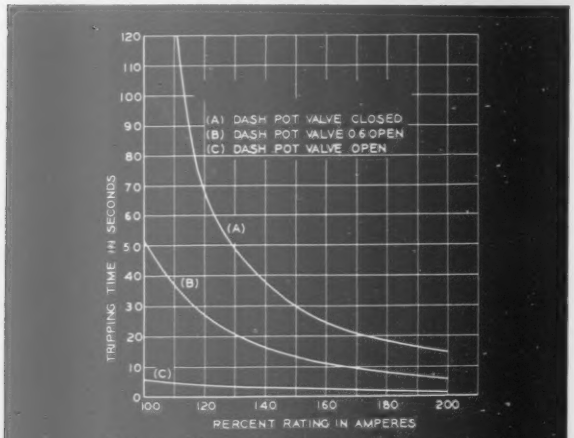


Fig. 1 — Magnetic Overload Relay with Oil Dash Pot

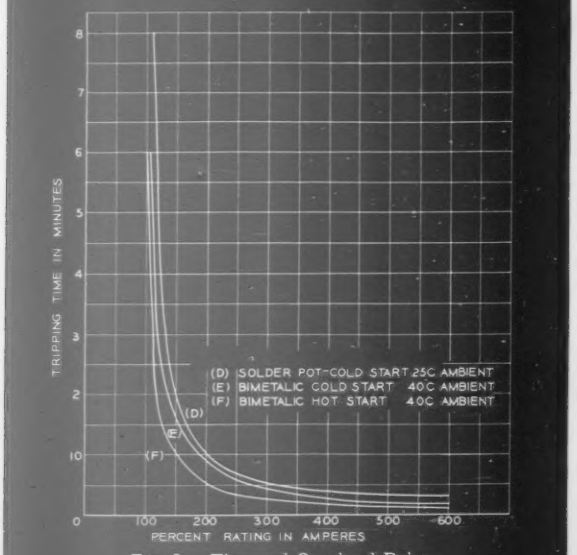


Fig. 2 — Thermal Overload Relays

The Underwriters' Laboratories have set up definite standards for thermal relays. One requirement is that the relay must trip out at its rated current within two hours in an ambient temperature of 40 C. Another is that the heater element of the relay must not fuse on a circuit of 5000 amperes with a fuse rated at four times the heater rating ahead of it. The observance of these rules tends to put all thermal relays, regardless of manufacture, on an equal basis.

Although many variations in thermal relays have been tried, there are only two types in common use—the bimetallic and the solder pot. They are alike in that each has a heater element through which the motor current or current transformer secondary current is passed. They differ in that the heat thus developed causes deflection of a bimetallic ribbon in one and melting of an eutectic solder in the other.

Typical characteristic curves for these relays are shown in Fig. 2, curves D, E, and F. Note the general hyperbolic shape which fulfills the requirements mentioned in the first paragraph.

Unlike the magnetic or induction relay, the thermal relay integrates repeated load peaks of short durations so as to cause tripping if the motor is over-heated. The thermal relay does not provide short-circuit protection. If short-circuit protection is required, the usual practice is to back up the thermal relay with an induction relay set to trip at or slightly above locked rotor current.

Several other types of relays are available to meet special requirements, such as long starting period, low starting current, etc. Since these are usually designed for the individual motor and application, it is not feasible to cover them in this brief discussion.

H. A. WRIGHT.

ON FOLLOWING PAGES: Finish machining the shaft of a Kaplan type hydraulic turbine. In the foreground is the hub for the removable propeller blades.

MAKING HOME SWEET HOME

O. L. Parsons

HOME APPLIANCE DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

Cool in summer . . . warm in winter—how many times have you wistfully wished that was a definition of your home? Today the average home owner buying a new heating plant is air-conditioning conscious, but many do not get all the advantages afforded by a modern home conditioner.

● Because he has seen air conditioning accepted by the local theatres and restaurants, as well as by his neighbors, the average home owner buying a new heating plant will choose some modified form of air conditioning system for his own home. The system this average owner finally decides on will give him some but not all of the services of complete air conditioning. It will heat his home, remove dust from the air, humidify, and keep the air in circulation. It probably will not cool his home, nor will it dehumidify the air, nor remove odors, because he feels these services cost more than he considers them worth.

Physiological effect of temperature and humidity

There is no one air condition at which everybody will feel comfortable. The nearest possible approach, 70 F, and 50 percent relative humidity, will satisfy 97 percent in the wintertime, but three people in 100 will still feel too warm or too cold.

Normally, increasing the humidity of air makes it feel warmer, and increasing its velocity makes it feel cooler. At low temperatures, however, humidity has the opposite effect. At high temperatures, air motion has the opposite effect.

Perfectly dry air at 70 F feels about seven degrees cooler than 100 percent humid air at the same temperature because the dry air evaporates moisture from the body more rapidly. Below 45 F (for still air), however, evaporation is no longer a factor, and increase in the humidity makes the air feel colder because its specific heat is increased.

Average air at 70 F will feel about seven degrees cooler if in rapid motion than it will feel at rest because the air motion speeds up both evaporation and direct conductance of heat from the body. However,

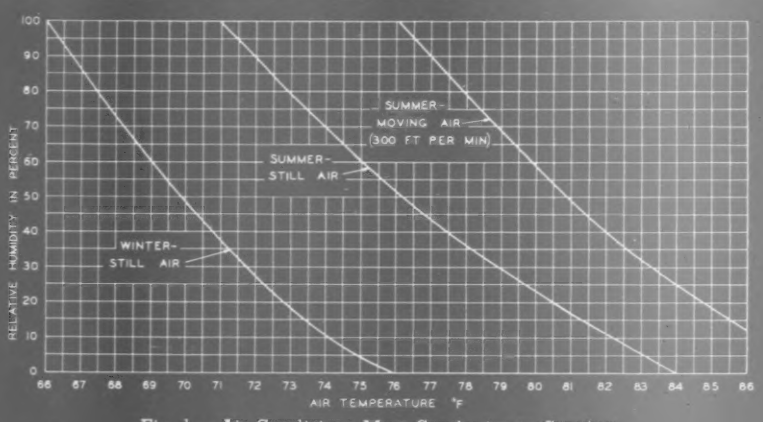


Fig. 1 — Air Conditions Most Conducive to Comfort

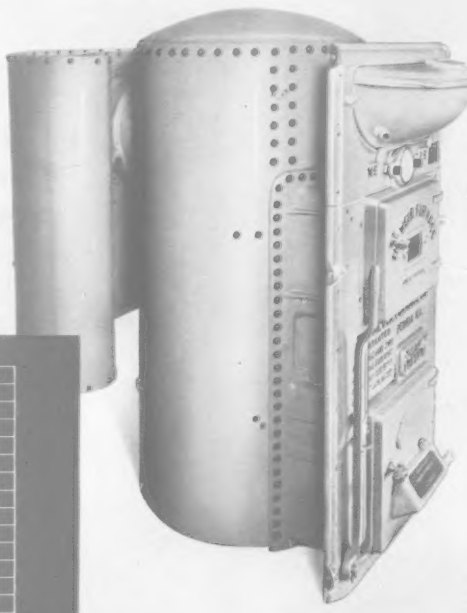


Fig. 2

above the point where heat is carried to the body by the air (body temperature for 100 percent humid air, 110 F for 65 percent humid air), increase in air motion naturally makes the air feel warmer rather than cooler.

An "effective temperature" scale has been set up to correlate the several factors and give a measure of how warm the air will feel under various conditions. An effective temperature of, say, 70 F refers to conditions which will make the air feel the same temperature as 70 F, 100 percent humidity, still air feels. The proper conditions to maintain the ideal winter effective temperature of 66 F and the ideal summer effective temperature of 71 F are shown in the chart, Fig. 1.

Effect of air pollution

Air pollution has a decided physiological effect, but the exact extent depends on individual sensitiveness.

Many allergic conditions are now agreed to be caused by pollen or other solid matter in the air, and cases of hay fever, asthma, and eczema can frequently be traced to this cause. Often ordinary house dust is the cause of an outbreak in a person having this particular allergy. Related and far more frequent are the many cases in which certain odors or stuffy air, frequently not objectionable to others, bring on headaches or upset digestion.

Contrary to former beliefs, it is now thought stuffy air is objectionable, not because of the reduced oxygen content or increased carbon dioxide, but because of increased quantities of moisture or of body or other odors.

Heating

Heating is, of course, the Number One service to be performed by a household air conditioner, and the primary problem is the generation of heat. The generator will be either an oil or gas burner or a stoker (automatic heat), or else a grate which is hand fired. The user should pay particular attention to the burner he selects, for on its reliability depends his satisfaction with the entire installation.

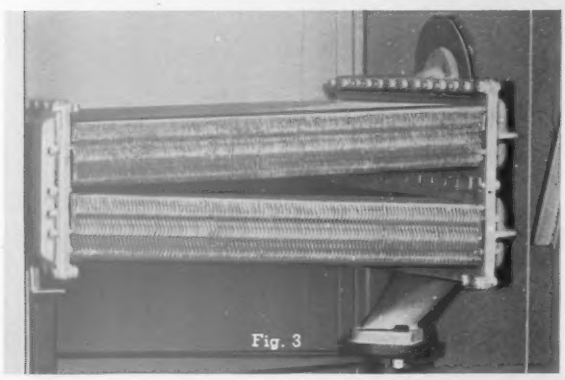


Fig. 3

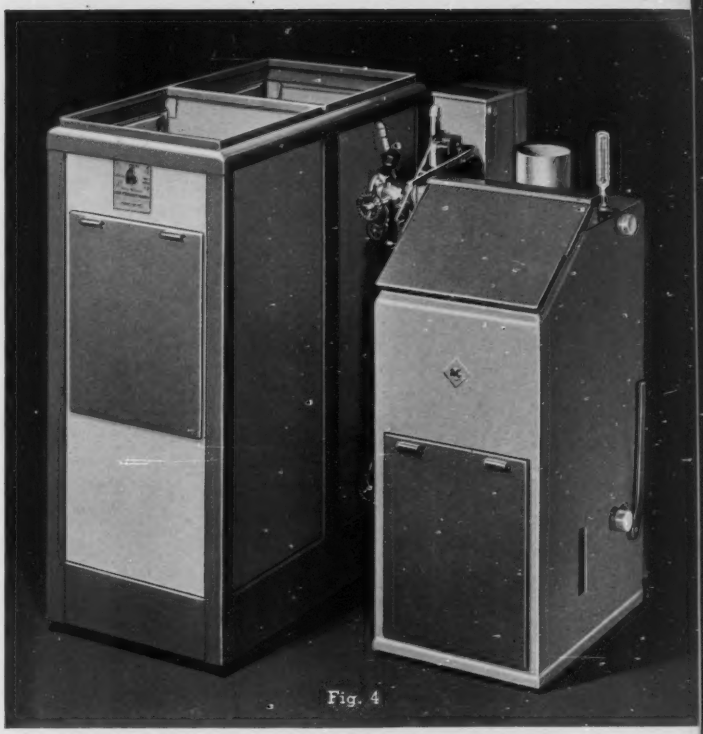


Fig. 4

The usual air heating arrangement is the direct fired furnace (Fig 2), the air being heated by passing over the hot firebox and radiating surfaces. An interesting method, the indirect system, is gaining in favor as its cost is being reduced. With this system (Fig. 4) the air is heated by a steam or water radiator (Fig. 3), the heat source being a boiler. Absolute cleanliness of the air, freedom from hot smells due to overheated surfaces, ability of the boiler to store heat and so smooth out the ripples in the heat generator curve of an off-and-on burner, at least some summer cooling inherent in the unit, and a uniform hot faucet water supply available from the separate boiler are its main advantages over the direct fired system.

Cooling

Cooling is accomplished by passing the air over a chilled coil. (Air washers for cooling are little used for residential work.) The chilling can be accomplished by mechanical refrigeration, by cold water if locally available, or by ice.

Mechanical refrigeration is highest in cost of equipment, usually intermediate in cost of operation. The apparatus consists of a standard motor-compressor condensing unit, the refrigerant generally expanding directly into the air cooling coil.

Fig. 5

Water cooling is practical if the available water is 20 degrees or more cooler than the room temperature to be maintained. Of the three cooling methods mentioned, water cooling results in the lowest operating and installation costs. A large coil, frequently of two or more passes, is used in order to obtain a sufficient cooling effect from a minimum water flow.

Ice cooling equipment is relatively simple, but the operating cost is usually the highest of the three methods. Ice is melted in a bunker to chill either water or brine, the latter being circulated through the cooling coil.

In order to compare the operating cost of the three cooling methods, the following approximations are useful:

1. The cost of cooling will be the same for the three methods if costs are in the proportion of 2.7 cents per kwhr for electricity, 15 cents per thousand gallons for water, and 3.6 cents per 100 pounds for ice.

   This does not include the cost of condenser cooling water used with mechanical refrigeration.

2. To provide one ton (12,000 Btu per hour) of cooling will require each hour one kwhr of electricity, 180 gallons of water, or 75 pounds of ice. (A small house requires about two tons of cooling.)

In an indirect heating system, the heating radiators may also be utilized as the cooling means by connecting the radiators to a source of cooling water or brine.

Humidifying

The usual type of humidifying device is the open pan, although the spray type is also used.

A principal consideration for satisfactory humidification is that lime from the water shall not affect the humidifier's functioning. To replace the moisture normally carried out of the house by air leakage requires adding many gallons of water to the air every twenty-four hours; and in the course of a year evaporation of this water, especially if it is very hard, deposits a great deal of lime. If the water is softened, an equal amount of solid material is still dissolved in the water, though its chemistry has been changed.

After a few months' operation on hard water, a small humidifier pan will become filled with lime, small delicate water feed valves will be put out of commission, and any blotter-like material used to extend the evaporating surface will become clogged. With a spray humidifier each drop of water on evaporating will leave a tiny portion of entirely non-volatile salt behind it, which if not removed in the air conditioner, may be deposited on furniture or elsewhere in the house, the resulting accumulation being suggestive of Portland cement dust.

If naturally soft water is available, the humidifier problem is not difficult. If only hard or softened water is available, a large pan and large simple valve protected from heat should be used to insure reliable operation.

Dehumidifying

Removing moisture from air is a problem much more difficult than adding moisture. The most common method is to combine dehumidifying with cooling, on the principle that air if cooled sufficiently will condense out its moisture. For example, air at 80 F and 70 percent relative humidity, if cooled to 50 F, will lose half its moisture, so that if it is again heated to 80 F its relative humidity will be only 35 percent. Further, it is desirable to combine cooling and dehumidifying because the two are required at the same time.

Other methods of dehumidifying usually employ a material such as silica gel or activated alumina, which has physical surface attraction for moisture; or lithium chloride or calcium chloride, which have a chemical affinity for moisture. The apparatus, however, is usually too expensive and requires too much attention for average household use.

Some conception of the problem and the heat quantities involved in cooling and dehumidifying can be obtained from the following example: if a thousand cubic feet of air at 80 F and 70 percent humidity is cooled to 50 F (which will remove half the moisture, as pointed out above), 1040 Btu will have been removed, 580 Btu of which is used to condense the moisture (0.55 lb will be removed), the remaining 460 Btu to actually cool the air.

Cleaning

The dry throw-away filter is the accepted air cleaning device for domestic use since it requires no gadgets and only once-a-year attention.

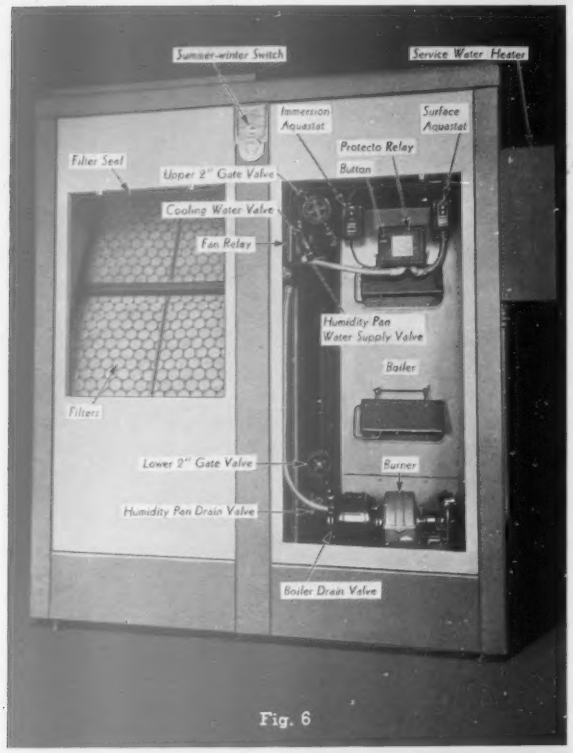


Fig. 6

The filter consists of a square cardboard frame filled loosely with glass wool (Fig. 5), animal hair, corrugated cardboard, punched manila paper or other material, depending on the make of filter. On this filler is sprayed an oily substance which acts as the dirt-catching medium. Dust particles impinging on the filter are caught and held by the stickiness of this oil. This type of filter catches well over 90 percent of the dust in the air passing through it. There are three or four filters in the average air conditioning unit (Fig. 6); and, when filled with dust, they are replaced with new ones. Although dust content of the air in different installations varies and so affects filter life, the average life is about a year.

Odor treatment

Filters will remove solid matter such as dust, but will not remove most odors, which are gaseous. The recognized method of treating odors is to simply bring in sufficient outside air to dilute them. In most instances no special provision is needed in residences, normal air leakage being sufficient. Materials such as activated charcoal are available to absorb gaseous contamination but are not greatly used in residential installations.

The addition of desirable odors is simple. Suitable material, usually a liquid, is simply sprayed into the air. Many preparations to give the odor of pines, flowers, etc., are available.

The invigorating smell of fresh country air has not yet been successfully produced artificially. It very likely will be synthetically produced in the near future. The invigorating effect is believed to be due to minute quantities of various odors in the air produced by trees and other vegetation.

Requirements for a home air conditioning unit

Aside from size, the requirements of an air conditioning unit for home use differ from those of a commercial installation principally because, first, the unit must be very low in purchase and operating cost and, second, there is no skilled operator constantly on hand to supervise its functioning.

Mass production fortunately brings prices down to the point where the purchaser receives a great deal for his money. Even so, for price reasons, the average householder usually passes up summer cooling, buying a "modified winter air conditioner." Operating cost has been consistently reduced, especially in the better grades of equipment, by increase in the efficiency of burning fuel. Eighty percent efficiency — 80 percent of the heat available in the fuel being delivered to the house — is not at all uncommon performance with units now available.

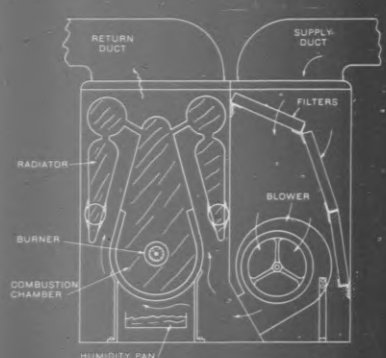


Fig. 7 — Sectional View of a Typical Direct Fired Unit

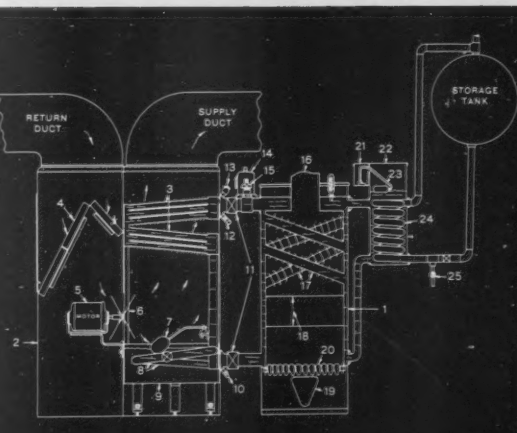


Fig. 8 — Sectional View of a Typical Indirect Fired Unit

1. Boiler
2. Air Conditioner
3. 2-Pass Radiator
4. Air Filter
5. Motor
6. Propeller Type Blower
7. Humidity Pan Float Valve
8. Humidity Pan Heating Coil
9. Humidity Pan
10. Drain Valve
11. Gate Valve
12. Cold Water Supply Valve
13. Radiator Pop Valve
14. Damper Motor
15. Bellows Damper
16. Smoke Pipe
17. Finned Water Tubes
18. Fuel Opening
19. Draft Port
20. Grates
21. Fill Tank
22. Expansion Tank
23. Expansion Tank Float Valve
24. Indirect Coil Heater
25. Coil Blow Out Valve

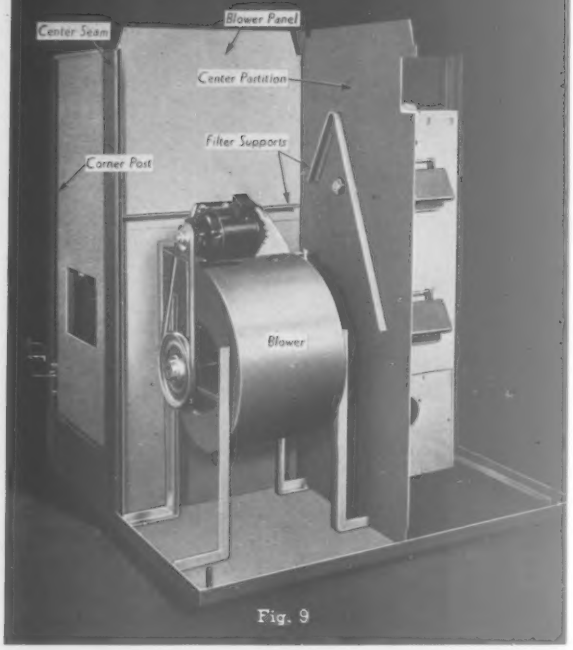


Fig. 9

Reliable performance requiring a minimum of attention has been developed in the air conditioning field, as it has been in other fields, by constant trial and development, noting carefully causes of failure and constantly modifying design to overcome recurrence of these failures. The parts of an automatically controlled oil burner or stoker, for instance, must perform an exceedingly large number of functions; yet it is not unusual for one of these devices to run a full twelve months without service attention.

The complete unit

Such air conditioning apparatus as the designer plans to use is ordinarily combined into a single unit to be located in the basement or utility room and connected to each of the principal rooms by one or possibly two supply and return air ducts (see Figs. 7, 8, and 9).

Though there are many variations, in one arrangement the air passes in order through the filters, the blower, over the humidifier and then over the heating and possibly cooling surfaces. Any odor treatment can be placed just after the filters. The entire apparatus is regularly enclosed in a sheet metal housing of attractive appearance (see Fig. 10).

Controls

Proper controls are necessary to coordinate the operation of the unit and to maintain an even temperature, particularly in the winter. The usual temperature control on a direct-fired unit consists of a room thermostat and a bonnet thermostat in the heating unit. When the house requires heat, the room thermostat starts or accelerates combustion, which in turn heats up the furnace. When there is sufficient heat at the top of the furnace, the bonnet thermostat starts the blower, to deliver air and with it, of course, heat to the rooms.

The usual indirect system controls have the room thermostat directly connected to the blower so that, when heat is required, the blower is started. This gives instant response and, consequently, closer control of the room temperature. Other controls maintain the boiler temperature or pressure.

On an automatic heat unit there is at least one safety control, in addition to the controls mentioned above, to prevent overfiring, explosion, or in the case of a stoker, fire outage.

Humidity control, widely used some years ago, is now frowned on by many because of the possibility of someone in ignorance setting the control at a humidity (e. g. 70 percent relative humidity in 20 below zero weather) which will damage the house. A humidifier which of its own accord will maintain say 30 percent in below zero weather and 55 percent in 40 F weather is to be preferred.

Cooling units in some cases use a room thermostat to start and stop the cooling process; in other cases the cooling operation is simply started manually and permitted to run continuously. As a more or less constant differential between outside temperature is more desirable than a fixed inside temperature, the latter method is frequently satisfactory.

Fig. 10

CAN YOU KEEP A SECRET?

D. Journeaux

PATENT ATTORNEY • ALLIS-CHALMERS MANUFACTURING COMPANY

What to do — keep your newly invented process or machine a secret . . . or expose it to competition by getting a patent?

● During the one hundred and fifty odd years of its existence, this country has fostered inventions in such numbers that the records of the United States Patent Office alone have entered them by the million.

Naturally only a few of these inventions are of such importance as to affect visibly our everyday life. Some fewer yet are familiar to most people because they were the starting points of articles of manufacture in daily use by the public at large. Among these figure Bell's telephone, Howe's sewing machine, the Wrights' airplane. Others equally important relate to manufacturing processes and machines which, being used in factories, are less in the public eye even if their products are well known to all. Among the most important are Whitney's cotton gin, Hall's process of making aluminum, Goodyear's vulcanization of rubber.

While the number of basically new articles of manufacture invented from year to year remains relatively limited, these articles are always susceptible to being rendered more attractive to the buyer, more advantageous, or cheaper to produce. Hence the evolution of numerous improvements day in and day out. Naturally, an improved article to be sold to the public, or at least to selected users, cannot very well be kept a secret by its inventor or manufacturer. To prevent its being copied lawfully by competitors the inventor of the article or of the improvement need only avail himself of the protection given by the patent system.

Both the improvement of the article itself and the reduction of its cost may be brought about by perfecting the methods or the machines used for its manufacture. In fact, up-to-date shop equipment and shop processes are indispensable in most manufacturing plants, now that practically everything, from safety pins to battleships, is made by mass production. When it comes to placing his patentable shop practices beyond the reach of his competitors, the manufacturer may usually take his choice of two policies. He may maintain these practices secret, or he may protect them by patents. There are good reasons in favor of the one and of the other method, and each may be preferred in some cases and discarded in others.

Inventions used in public

The first inventor of a new machine or process does not need to patent it to be able to use it himself. He has naturally the right to use it secretly or publicly provided that it does not infringe some existing patent held by somebody else. A patent merely secures to the patentee, i. e., the inventor or his assignee, the right to exclude others from practicing the invention for a limited number of years. A machine or a process susceptible of use only in full view of the public — a method of erecting bridges, for example — cannot very well be kept a secret. If a patent is obtainable thereon, it provides the obvious means of securing this exclusion of competitors from its use. The patent should be enforcible without excessive difficulty because the patentee is able to observe the activities of his competitors and thus detect infringements of his patent.

Inventions used in a factory

If the novel process or machine is used in a manufacturing plant, the grant of a patent to its inventor protects it also, at least on paper, against piracy by competitors. The patent may, however, be sometimes more detrimental than useful to the patentee. The inventor of the process or machine is required to describe it in such manner that "one skilled in the art or science to which it appertains" may be able to utilize it after reading the patent and, of course, after dutifully waiting for it to expire. To an unscrupulous competitor such a patent may be a boon, as it gives him the information he desires. He may then be able to pirate the invention freely, as infringement behind the doors of his factory may be difficult to detect and more difficult yet to prove to the satisfaction of a court.

Secret inventions protected only by common law

If patent protection appears to be illusory, attempts may be made by the manufacturer to keep his improved machine or process secret. He is then, naturally, taking the chance that another may rediscover

the improvement, use it freely, and even patent it. He may obtain a measure of security against communication of his secret to others only by rendering his process or machine accessible to the least possible number of employees and pledging these employees to secrecy. If one of the pledged employees then surreptitiously discloses the improvement to a competitor, this unfaithful employee and the competitor may be enjoined from using it because of the breach of trust committed by the employee. Such redress can be obtained, not because of any intenton of Congress to favor secret inventions, but because of the general principle of common law that one having committed a wrong — a breach of trust in this instance — cannot be permitted to profit thereby.

Rather than favoring secret inventions, the Constitution implicitly condemns them in laying the foundation for the patent system, which has as one of its objects to bring about the public disclosure of inventions. The secretive inventor is left by the statute to his own devices. He is acting contrary to public policy, and the Supreme Court has repeatedly taken special care to hurl its loudest thunder in his direction. In one case, it was held that:

> "The inventor who designedly, and with the view of applying it indefinitely and exclusively for his own profit, withholds his invention from the public, comes not within the policy or objects of the Constitution or Acts of Congress. He does not promote, and, if aided in his design, would impede, the progress of science and the useful arts. And with a very bad grace could he appeal for favor or protection to that society which, if he had not injured, he certainly had neither benefited nor intended to benefit."

Commercial use in factory may be secret or public

There is thus no doubt as to the precarious protection of the inventor who, having practiced his invention commercially in his own plant for several years, sees a competitor use the same invention and tries to stop him by taking out a patent thereon. In general, the Patent Office will assume that, as represented by the inventor under oath, the invention has not been in so-called public use for more than a year (formerly two years were permissible) before the date of his application. If the patent is granted, the infringing competitor sued thereunder may allege that the patent is invalid, because the patentee himself put the invention in "public use" for such length of time as to bar the grant to him — or to anybody else — of a valid patent thereon.

The natural reply of the patentee to such defense is that he practiced his invention, albeit commercially, behind closed doors and hence not in public. But such commercial use of an invention can be so secret as to be known only to the inventor himself, and again it may be known to many members of the public. The circumstances of each case must be considered separately to determine which uses might be held public, and which secret. And it is difficult to draw a sharp line between secret and public uses when the circumstances of different adjudicated cases, like the hues of the rainbow, merge into one another by imperceptible degrees.

Patent valid over prior secret use by assignee

For example, the patent on the machine illustrated in Fig. 1 was held valid although the inventor's assignee had used the machine commercially for more than two years before the patent was applied for. The machine was accessible only to the few workmen assigned to use it, who were, however, not pledged to secrecy. On the basis of the evidence submitted, the court held that:

> "When the number of these is limited to as few as are necessary to practice it at all, when customers and the public generally are excluded, and adequate precautions are taken to prevent dispersion of the knowledge until at least two years before application is made, it seems to us enough, whether a formal pledge of secrecy be exacted or not. . . . When, as here, adequate means are taken to confine all information as closely as is consistent with any exploitation at all, and when, so far as appears, they are successful, the knowledge of the necessary workmen not explicitly pledged to secrecy does not make the use public."

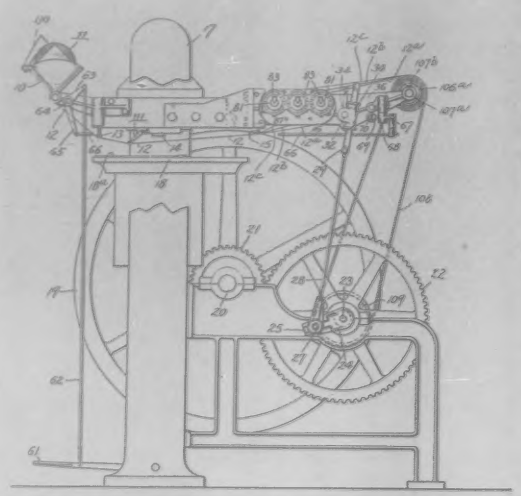


Fig. 1 — W. F. Grupe's stamping machine with automatic feeder for the strips of gilt paper used in printing titles on book covers and in decorating other articles. The patent was held valid in 1928 although the machine had been used commercially in secret over two years before the patent was applied for in 1924.

Patent invalidated by prior public use by patentee

Less fortunate was another inventor, whose patent on the machine illustrated in Fig. 2 was held invalid. He used his machine for several years in his factory, to which the general public did not have access. There were occasional visitors, but not many persons came to the factory "from mere curiosity." Under the circumstances the court felt constrained to rule that:

> "It has always been held that when the public have had means of knowledge they have had knowledge of the invention. Thus if a book has been published describing the invention, it is not important that no one has read it. . . . If a pier has been placed in the bed of a river, or a pipe under ground, it is conclusively presumed to be known to all men. . . . It is enough that any one or more persons, not under a pledge of secrecy, saw the invention practiced, or even might have seen it if they had used their opportunities, provided it was in fact practiced in the ordinary way after being completed. And it must be held either that the workmen and visitors were a part of the public, or that they were persons from whom the public might have acquired the art without a breach of trust."

It may well be asked how much those who actually have seen an invention in use in a factory need to have learned therefrom to render its use public. In another decision a court ruled it not essential to be established

> "that persons who witness the prior public use of an anticipating device understood and appreciated its method of operation. That, too, in a practical sense, is more than can be asked. A prior use of an invention may be public, even though the portion of the public who witnessed it are not skilled in the art to which the use appertained."

Having due regard for particular circumstances, it may be considered that, as tersely expressed by the Supreme Court in a recent decision:

> "A mere experimental use is not the public use defined by the Act, but a single use for profit, not purposely hidden, is such. The ordinary use of a machine or the practice of a process in a factory in the usual course of producing articles for commercial purposes is a public use."

Secrecy is abandonment of right to patent

Another and perhaps more dangerous pitfall than "public use" lies in the path of the inventor who, having reaped the benefits of secrecy, seeks yet to reap those of statutory exclusion and, feigning repentance, finally discloses his invention in return for a patent. If this secret use of the invention extended over a period of years, an infringer sued under the patent may very well plead that the inventor had, by his actions, rendered his patent void. By choosing secrecy, he "abandoned" his invention so far as the Courts are concerned and, by law, he should not have received a patent if his invention had been "proved to have been abandoned." This may seem arbitrary, but after all, "Congress, having created the monopoly, may put such restrictions upon it as it pleases." And such restrictions are clearly dictated by public policy. The intentions of Congress were authoritatively clarified in this respect by the Supreme Court, which held as long as a hundred years ago that:

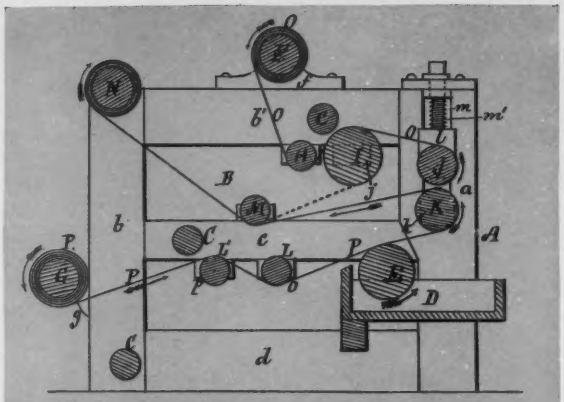


Fig. 2 — E. L. Perkins' machine for joining two strips of paper by a thick layer of paste to form stiff cardboard. A leading court decision handed down in 1880 held the patent invalid because of commercial use of the machine without secrecy over two years before the patent was applied for in 1876.

> "If an inventor should be permitted to hold back from the knowledge of the public the secrets of his invention; if he should for a long period of years retain the monopoly, and make, and sell his invention publicly, and thus gather the whole profits of it, relying upon his superior skill and knowledge of the structure; and then, and then only, when the danger of competition should force him to secure the exclusive right, and he should be allowed to take out a patent, and thus exclude the public from any further use than what should be derived under it during his fourteen years (seventeen under the present laws); it would materially retard the progress of science and the useful arts, and give a premium to those who should be least prompt to communicate their discoveries."

The Supreme Court also recently cited with approval a lower court decision drawing from the above its conclusion that:

> "Not to accept the benefit of the patent laws, but to rely upon the trade secret law for protection of an inventor, is as clear an abandonment by him of the privileges and obligations of the patent law as the abandonment of its advantages in any other manner would be."

Public use protects against later inventors

If a machine or process is used in the privacy of a factory without attempt at complete secrecy, the invention may be stolen, at least in its essential features, by unscrupulous visitors. On the other hand, such use, being public, will render invalid the patent

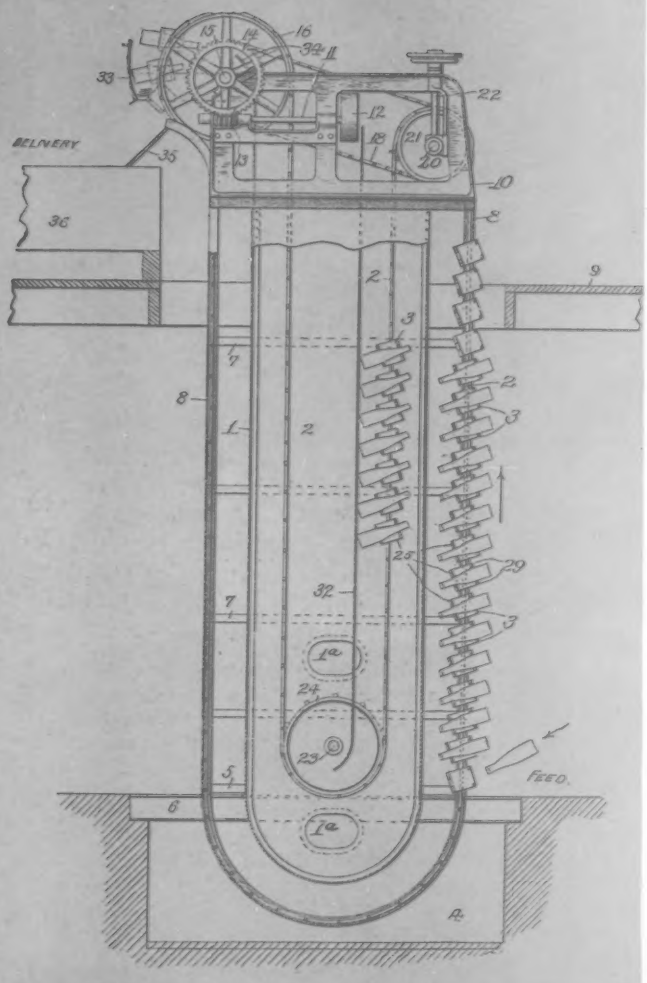


Fig. 3 — S. Volz' machine for soaking beer bottles in a cleaning solution. The patent was held invalid in 1917 because a similar machine had been invented and installed in a brewery by an earlier inventor, who, however, did not apply for a patent.

of even a prior inventor if he has waited until the public use had continued for more than a year before applying for his patent.

If this machine or process is later reinvented by one who believes himself to be its first inventor, his application for patent will be rejected or, if a patent is improvidently granted to him it will be invalid. Judged by Patent Office standards he is not the first inventor. Thus the public-behind-closed-doors use of the invention protects the user against successful interference by later inventors just as effectively as if it had been given world-wide publicity or even been patented.

In this connection, a bottle-making machine installed in a brewery rendered invalid the patent on the later machine illustrated in Fig. 3. Although the public at large had no knowledge of it, the machine was built and used without attempt at concealment before the patentee himself independently completed the invention, and "Prior knowledge and use by a single person would have been sufficient to require denial of the patent." If, however, the use of the machine had been purposely and successfully maintained secret until brought to the attention of the court by any imaginable chain of circumstances, the conclusions of the court might have been different.

It may be mentioned that the inventor who has elected to put his invention in public use may find it desirable also to try to patent it. He must, however, file his application within one year from the beginning of the public use; otherwise his patent will be refused or, if improvidently granted, will be invalid. If he fails to file a timely patent application and, several years later, wants to stop his competitors from using his invention, he will be unable to do so, whether the invention was obtained by others from seeing it practiced in his factory or was reinvented independently. In that respect he is in the same situation as if he had abandoned his right to a patent by concealing his invention successfully.

If he chooses secrecy, however, not only is he entirely powerless to stop a competitor who has later invented the same invention, but he may even conceivably see this competitor obtain a valid patent thereon. And it should be borne in mind by anyone tempted to keep secret his contribution to the art that at the present stage of our industrial activity the same improvement is often invented independently by several inventors. This is evidenced by the numerous instances of patents for the same invention being applied for by several inventors, sometimes at the same time and sometimes one after the other. The protection afforded by secrecy, which may have been dependable when those acquainted with manufacturing problems were few and far between, therefore seems destined to become more and more illusory as the manufacturing industry continues to expand.

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WHAT EVERY ENGINEER SHOULD READ

There's a whimsical saying that a college education is harmless provided the college graduate is willing and able to resume his education after graduation. Nonetheless, here's a list of books that should be a "must" for the well-read engineer.

Perhaps the most harmful fallacy current in our midst is that a college degree denotes a complete education. Unless the college graduate has learned how to read and how to continue his education under his own supervision, the college course has but little value. And this is particularly true for our engineering graduates. So intensive is the course of technical study at engineering colleges that little time or desire is left for familiarity with those cultural subjects which are necessary to the making of a civilized man and a good citizen. It is therefore all the more important for the young engineer to lay out and follow a planned course of reading in cultural subjects.

For that reason, the Allis-Chalmers ELECTRICAL REVIEW takes great pleasure in reprinting the following Reading List, which was prepared by the Committee on Professional Training of the Engineers' Council for Professional Development. The Reading List is part of a pamphlet entitled "Suggestions to Junior Engineers" prepared by that committee under the chairmanship of the late General R. I. Rees and is reprinted with the permission of the Committee.

● Two of the most important attributes the successful engineer must possess are, first, the ability to deal with men and affairs and, second, the ability to read and absorb the written experience of others. These abilities are seldom found fully developed in any man. Generally, they must be developed by the individual himself and usually after formal education is completed.

The Reading List given here, based upon recommendations by a number of eminent men, many of them distinguished engineers, is presented especially for the junior engineer who is desirous of broadening himself and developing a full professional life. The titles are, we hope, suggestive and will attract the reader and lead him to explore further. It is expected that they will provide a basis on which the non-technical culture of the engineer can be continued.

A few words of advice may be in order. Over a period of about four years a minimum of twenty-five of these books might be selected and read, with the limiting recommendation that the selection made will include at least one book in each classification. Read a few books well and make their thoughts your own, rather than skim many and absorb nothing. Develop reading habits outside of your technical specialty — it will profit you much in enjoyment and mental stimulation. Since "reading maketh a full man and writing an accurate one," practice the reduction of your thinking into written words so that you may perfect yourself in accuracy of expression.

The general subject classification is as follows:

NATURAL SCIENCE
PHILOSOPHY, INCLUDING RELIGION
ECONOMICS AND SOCIOLOGY
PSYCHOLOGY
BUSINESS AND INDUSTRIAL MANAGEMENT
LITERATURE, INCLUDING POETRY, ESSAYS, AND FICTION
HISTORY
BIOGRAPHY AND TRAVEL
FINE ARTS
GENERAL

Natural science

BRAGG, WILLIAM. Concerning the Nature of Things. Harper, 1925.

A simple account, with many photographs, of the properties of atoms, and of the nature of gases, liquids, and crystals. Author is a pioneer in X-ray work.

DAMPIER-WETHAM, W. C. History of Science and Its Relation to Philosophy and Religion. Macmillan, 1929.

Evolution of scientific thought and research from dawn of history in Babylonia and Egypt, through the speculations of Greece, and past the blind alleys of the Middle Ages to the present.

DARWIN, C. G. New Conceptions of Matter. Macmillan, 1931.

Originally a series of lectures at Lowell Institute, Boston. Author is Tait Professor at University of Edinburgh. Presents the broad features of the new theoretical physics in non-technical terms.

EDDINGTON, A. S. The nature of the Physical World. Macmillan, 1928.

Takes up both relativity and the quantum theory and traces the effect of modern concepts on Free Will and Determinism.

HALDANE, J. S. Philosophical Basis of Biology. Doubleday, Doran, 1931.

Object of this volume is to present the theoretical basis of the nature of life which "biological observation seems to force upon us." Lectures were given under Donellen Foundation at Trinity College, Dublin.

JEANS, SIR JAMES. The Universe Around Us. Macmillan, 1934.

Later than his "Mysterious Universe." Man's increased knowledge has resulted in a new formulation of his relation to the universe. Presentation in simple and lucid style and, of course, authoritative.

KELLOGG, VERNON. Human Life as the Biologist Sees It. Henry Holt, 1922.

For the layman. Interprets in simple language what science teaches about mankind in its relationship to origins, heredity, everyday life, death, the soul, and the future.

MERRIAM, J. C. The Living Past. Scribner, 1930.

A study of evolution from plant and animal life as indicated in footprints, bones, leaf imprints, skeletons, and other remains found in various parts of the country.

NEWMAN, H. H. Nature of the World and of Man. Garden City Publishing Co., 1933.

Members of University of Chicago faculty have contributed the chapters outlining our present knowledge of the physical and biological world. A survey course designed to give capable students a preliminary view of the fields of scientific study which lie before them.

PILCHER, R. B., and BUTLER-JONES, FRANK. What Industry Owes to Chemical Science. Van Nostrand, 1931.

A fine resumé of advances made in metallurgy and manufacture and various commodities and the application of scientific research. Very readable and most compact and a convenient history of industrial chemistry.

RICKARD, T. A. Man and Metals. McGraw-Hill, Whittlesey House, 1932.

A history of mining in relation to the development of civilization from prehistoric times. The author is an authority and the book is full of information.

SHAPLEY, HARLOW. Flights From Chaos. McGraw-Hill, 1930.

The reader will find it valuable whether he knows little or much about astronomy. A good stretching exercise for the imagination.

THOMSON, SIR J. A. Modern Science. Putnam, 1930.

The author discusses this question: Will the teachings of astronomy and science change our outlook on the universe as a whole, and the meaning of human life? Book is valuable as a means of provoking thought.

VAN LOON, H. W. Geography. Simon & Schuster, 1932.

Popular geography, emphasizing the human interest side of the world we live in. Discusses why we live where we do, where we came from, and what we are doing.

Philosophy, including religion

BROWNE, LEWIS. This Believing World. Macmillan, 1930.

A fascinating account of the development of the chief modern religions.

CABOT, R. C. Meaning of Right and Wrong. Macmillan, 1933.

Discussion of the characteristics of right and wrong conduct as related to ordinary human experience, for people unfamiliar with philosophy.

DEWEY, JOHN. Philosophy and Civilization. Minton, 1931.

Might be described as "essays in experimental psychology." Form is more readable than that of his earlier books.

DURANT, WILL. Mansions of Philosophy. Simon & Schuster, 1929.

Survey of human life and destiny.

HOCKING, W. E. Types of Philosophy. Scribner, 1929.

History of the leading types of philosophy, with thorough comparative analysis. Intended for beginners in philosophical study.

JASTROW, JOSEPH. Effective Thinking. Simon & Schuster, 1931.

An informal account of thinking. Part I deals with the technique of thinking; part II with impediments to clear thinking; part III with constructive phases by which right thinking is guided and encouraged.

KEYSER, C. J. Humanism and Science. Columbia University Press, 1931.

Evaluation of science and mathematics as agencies for realizing the ideals of humanism.

LIPPMANN, WALTER. Preface to Morals. Macmillan, 1931 (Second ed.).

Written for those who are seeking for fundamental principles to govern their lives and actions and give point to modern life. Frank, vigorous, and thought-provoking.

SCHMIDT, NATHANIEL. The Coming Religion. Macmillan, 1930.

Survey of origin and development of religion to our times, and search for the direction in which religion is moving today. Author is Professor of Semitic Languages at Cornell.

STEPHEN, KARIN. Misuse of Mind. Harcourt, Brace, 1922.

This book is likely to open one's mind to unexpected possibilities; an excellent introduction to the philosophy of Bergson.

THOMAS À KEMPIS. Imitation of Christ. Macmillan, 1924.

For five centuries the Christian manual. Expresses with simplicity the yearning of the devoted worshipper for communion with God and Christ. Offers ethical counsel and personal guidance and is an unfailing source of comfort and inspiration.

Economics and sociology

BEARD, WILLIAM. Government and Technology. Macmillan, 1934.

An attempt to point out in general terms the important relation between the work of engineers in all fields, with the government, by which they may be employed or regulated.

CALVERT, W. J. Studies in Elementary Economics.

A simple, clear-cut presentation of economic theory; published by and obtainable from Mr. Calvert, Englewood, N. J.

CHASE, STUART. Economy of Abundance. Macmillan, 1934.

A discussion of the change of thought brought about by our transition from a scarcity to a surplus economy.

CHASE, STUART. Mexico: A Study of the Two Americas. Macmillan, 1931.

A thought-provoking contrast between two civilizations —the one based on handcraft and the other on machines.

COLE, G. D. H. Guide Through World Chaos. Knopf, 1932.

Survey of world crisis and its background of war conditions and in the light of capitalism of the past two centuries. Valuable material for discussion of communism and capitalism.

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Statement of fundamental sociological principles. Many concretely described social situations relating to urban life and economic activities.

FITCH, J. A. Causes of Industrial Unrest. Harper, 1924.

Judicial consideration of prevailing conditions and phenomena which cause and contribute to industrial unrest, but attempts no solution.

FLANDERS, RALPH E. Taming Our Machines. R. R. Smith, 1931.

Attainment of human values in a mechanized society. Written in popular manner; clear and simple. A fresh view of the world's present troubles.

HANSEN, A. H. Economic Stabilization in an Unbalanced World. Harcourt, Brace, 1931.

Treats: (1) International causes and instability; (2) Causes of world-wide unemployment; (3) Population stabilization; (4) Discussion of value of possible or desirable stabilized capitalism.

HUMPHREY, E. F. Economic History of the U. S. Century, 1931.

Narrative of economic development of U. S., for purpose of explaining conditions of today from a record of country's growth.

JACKS, L. P. Constructive Citizenship. Doubleday, Doran, 1928.

He has "brought into captivity many ideas which have waged solitary fight in isolated places, and has regimented them into such shape that they deal a smashing blow against mechanical schemes of social deliverance."

KELLER, A. G. Man's Rough Road. Yale University Press, 1932.

A study of age-old institutions — property, religion, and marriage, especially in primitive manifestations. Condensation of a four-volume work.

LYND, R. S. and MIDDLETOWN, H. M. A Study in Contemporary American Culture. Harcourt, Brace, 1929.

A painstakingly statistical, yet sympathetic appraisal of a typical small city.

MARX, KARL. Capital. Kerr, 1919.

A critique of poetical economy. Written originally to make plain the fallacy of capitalistic economy, and still held to be the source from which anti-capitalistic movements draw their constructive power.

MAYO, ELTON. Human Problems of an Industrial Civilization. Macmillan, 1934.

A valuable contribution to the study of the social side of industry and particularly timely in view of present conditions. Especially valuable to engineers, personnel managers, and industrialists.

MILL, J. S. Principles of Political Economy, with Some of Their Applications to Social Philosophy. Appleton, 1898.

Abridged edition, with critical, bibliographical, and explanatory notes and a sketch of the history of political economy by J. L. Laughlin.

MILLS, F. C. Economic Tendencies in the United States. Little, Ives, 1932.

Statistical study from 1900 to 1929 of economic conditions.

MUIR, RAMSAY. Interdependent World and Its Problems. Houghton, 1933.

Clear and simple book based on lectures at University of Leeds and Liverpool in 1932. Attempts to bring out political significance of world-interdependence. After showing conditions of transport and production resulting in world interdependence, the author devotes several chapters to an analysis of virtues and dangers of nationalism.

MUMFORD, LEWIS. Technics and Civilization. Harcourt, 1934.

The author divides the industry of Western Civilization into three phases: Eotechnic or pre-scientific, Paleotechnic or period of heavy machinery dependent on coal and iron, and Neotechnic, the coming age of electrical power and decentralized units. Clarifying and stimulating discussion of relation of machine industry to human living generally. Exhaustive bibliography.

SALTER, SIR ARTHUR. Recovery: The Second Effort. Century, 1932.

Analyzes the broad causes which have brought the world into the present state of distress, and indicates new requirements, economic, financial, and political, upon which to base a new world order.

SIEGFRIED, ANDRÉ. America Comes of Age: A French Analysis. Harcourt, Brace, 1927.

Analysis, by a keen observer, of our ethnic, economic, and political situation. Displays extraordinary insight into the characteristics of American civilization.

SMITH, ADAM. Wealth of Nations. Putnam, 1904.

Inquiries into the nature and cause of wealth of nations. A landmark in history of thought, but parts are now out of date.

Psychology

ACHILLES, P. S., et al. Psychology at Work. McGraw, Hill, 1932.

Material derived from a series of lectures arranged by the Psychological Corporation in 1931; gives a good idea of a few things being done today in the broad field of applied psychology.

ADAMS, SIR JOHN. Everyman's Psychology. Doubleday, 1929.

Book of applied psychology written in terms the layman can readily understand. Recent psychological tendencies and schools are presented, questions of individual adjustment taken up, and studies of emotion and instinct as applied to individual development discussed.

EDMAN, IRWIN. Human Traits and Their Social Significance. Houghton, Mifflin, 1920.

Introduction to contemporary civilization. Processes of human nature from man's simple inborn impulses and needs to their most complete fulfilment in relation to art, science, and morals.

OVERSTREET, H. A. About Ourselves. Norton, 1927.

Psychology for normal people.

ROBINSON, E. S. Man as Psychology Sees Him. Macmillan, 1932.

Man, and comments on his nature; psychology, its aims; a lucid exposition of what psychology is accomplishing in helping man to self-understanding.

SMITH, ELLIOTT DUNLAP. Psychology for Executives. Harper, 1934.

Deals with themes such as habits and how to handle them, personality, self-control, and the effect of group psychology in industry.

VITELES, MORRIS. Science of Work. Norton, 1934.

The application of sound principles of psychology in the field of industrial relations.

Business and industrial management

DAVIS, HOWARD L. The Young Man in Business. Wiley, 1932.

Simply written book on vocational guidance by a director of such activities in industry; of particular interest to young people.

DENNISON, HENRY. Organization Engineering. McGraw-Hill, 1931.

Well written and shows original observation and analysis. Intended as an overall picture of the whole problem rather than as a discussion of specific situations. Intent is to encourage further systematic development of the art and science of organization engineering.

EIDMAN, F. L. Economic Control of Engineering and Manufacturing. McGraw-Hill, 1931.

Purpose of this book is to focus attention on economic aspects of engineering. It presents practical methods and techniques for solution of major industrial problems.

KIMBALL, DEXTER S. Principles of Industrial Organization. McGraw-Hill, 1933.

New edition fully revised and containing new material on such subjects as measures of management, mechanization of industry and factory arrangement, and production control.

SCHELL, E. H. Technique of Executive Control. McGraw-Hill, 1930.

Straight thinking applied to the duties and difficulties of the executive, with stimulating questions based on the problems presented.

TEAD, ORDWAY. Art of Leadership. McGraw-Hill, 1935.

Stresses the importance of organization in life of today, and analyzes the nature of leadership.

Literature, including poetry, essays, and fiction

The mark of an educated man is a general familiarity with great literature. The minimum for English-speaking people should be the Bible and Shakespeare. There are many other great writers and poets, and among them the young engineer will find a sympathetic spirit whose works will give him stimulus or repose as he wishes. Intimate acquaintance with a few of the world's great writers is to be desired and the following books are suggested as introductory only. A small library of great literature is a vital part of a busy man's relaxing equipment.

AUSLANDER, J., and HILL, F. E. The Winged Horse. Doubleday, 1928.

HOUSMAN, A. E. Name and Nature of Poetry. Macmillan, 1933.

A personal definition of its functions states that its aims must be to "transmit emotion — not to transmit thought." Nothing on modern poetry.

QUILLER-COUCH, SIR ARTHUR, edited by. Oxford Book of English Verse. Oxford University Press, 1910.

SHAKESPEARE, WILLIAM. Plays and Sonnets.

VAN DOREN, MARK, edited by. American Poets. Little, Brown, 1932.

Selections from fifty-seven poets from 1630 to 1930.

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CARLTON, W. N. C. English Literature. American Library Association, 1925. Reading with a Purpose Series.

HUBBELL, JAY B. Enjoyment of Literature. Macmillan, 1929.

HUXLEY, JULIAN. Essays of a Biologist.

LAMB, CHARLES. Essays of Elia.

PATER, WALTER. Marius the Epicurean.

PERRY, BLISS, edited by. Emerson's Journals. Houghton, Mifflin, 1926.

ROGERS, ROBERT E. The Art of Reading.

SHEPARD, ODELL, edited by. Thoreau's Journals.

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BALZAC, HONORE DE. Pere Goriot.

BRONTE, EMILY. Wuthering Heights.

BUCK, PEARL. The Good Earth.

BUTLER, SAMUEL. The Way of All Flesh.

CATHER, WILLA. My Antonia.

CONRAD, JOSEPH. Lord Jim.

DICKENS, CHARLES. Tale of Two Cities.

DOSTOYEVSKY, FEODOR. Brothers Karamazov.

FIELDING, HENRY. The History of Tom Jones.

GALSWORTHY, JOHN. Forsyte Saga.

HAMSUN, KNUT. Growth of the Soil.

HARDY, THOMAS. Tess of the d'Ubervilles.

LEWIS, SINCLAIR. Arrowsmith.

MALORY, SIR THOMAS. Morte d'Arthur.

MAUGHAN, SOMERSET. Of Human Bondage.

ROLLAND, ROMAIN. Jean-Christophe.

ROLVAAG, O. E. Giants in the Earth.

SHAW, GEORGE BERNARD. Plays.

STEVENSON, R. L. Treasure Island.

THACKERAY, WILLIAM MAKEPEACE. Vanity Fair.

TOLSTOI, COUNT LEO. War and Peace.

UNDSET, SIGRID. Kristin Lavransdatter.

WHARTON, EDITH. Ethan Frome.

History

ADAMS, JAMES T. Epic of America. Little, Brown, 1931.

An inspiring narrative of the evolution of the American nation.

BREASTED, J. H. Conquests of Civilization. Harper, 1926.

A summary of human progress from the crude beginnings of civilization to the fall of Rome.

BRYCE, VISCOUNT JAMES. American Commonwealth.

An interesting and keen analysis of our government by an authoritative British author.

BUELL, R. L. Europe: A History of Ten Years (1918-1928). Macmillan, 1929.

An account of the drift of Europe during this time, by the research staff of the Foreign Policy Association. Traces history of Paris Peace Treaties and the internal development of leading countries, and attempts to interpret Bolshevism and Fascism.

CHAMBERLIN, WILLIAM HENRY. Soviet Russia: A Living Record and a History. Little, 1931 (Second ed.).

By a man who has spent most of his time during the past fifteen years in Russia and whose evaluation is just and well-considered.

HAYES, C. J. H. Historical Evolution of Modern Nationalism. R. R. Smith, 1931.

Discussion of nationalism as a political philosophy, formulated by leaders of thought and opinion, instead of a social process or a popular movement.

WELLS, H. G. Outline of History (new and revised). Garden City Publishing Co., 1931.

A readable commentary on the life of man from the time of the Stone Age.

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CHARNWOOD, LORD GODFREY. Abraham Lincoln. Henry Holt, 1916.

DANA, R. H. Two Years Before the Mast. Macmillan, 1923.

FRANKLIN, BENJAMIN. Autobiography.

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LENARD, PHILIPP. Great Men of Science. Macmillan, 1933.

Biographical sketches of about ten pages each, of more than fifty outstanding scientists from ancient times to the World War.

MEREZHKOVSKI, D. S. Romance of Leonardo da Vinci. Translated by Herbert Trench. Putnam.

PARKS, G. B., edited by. Travels of Marco Polo.

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PUPIN, MICHAEL. Immigrant to Inventor. Scribner, 1923.

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THAYER, W. R. Life and Letters of John Hay. 2 vols. Houghton, Mifflin, 1915.

Fine arts

BUCK, PERCY. Scope of Music. Oxford University Press, 1924.

A series of ten lectures on physics of sound, origin, and place of music as an art, the nature of beauty, melody, form, and psychology of music.

BULLEY, M. H. Simple Guide to Pictures and Painting. Dutton, 1928.

Deals with principles of construction—design, personality, craft, tradition, and ways in which a painter works. Outlines the development of painting from Byzantine to modern French.

CRAVEN, THOMAS. Men of Art.

GARDNER, HELEN. Art Through the Ages. Harcourt, Brace, 1926.

World survey of history of art — architecture, painting, sculpture, and the minor arts from earliest times to the present.

HAMLIN, T. F. Enjoyment of Architecture. Scribner, 1921.

Fine explanations for laymen of basic principles of architectural design and construction, ancient and modern structures, with special attention to American buildings.

ISAACS, E. J. R., edited by. Theater. Little, Brown, 1927.

A collection of thirty essays on the art of the theater.

MOORE, DOUGLAS. Listening to Music. W. W. Norton, 1932.

Analysis, interpretation, and appreciation through intelligent listening. No previous training in music is required.

General

BACON, V. C. Good English. American Library Association, 1928. Reading with a Purpose Series.

BARKER, M. P. Technique of Good Manners. Wiley, 1935.

A series of lectures prepared for student engineers on the value of a good personality and a knowledge of sound social conventions.

DICKINSON, G. LOWES. The Greek View of Life.

FISHBEIN, MORRIS. The Human Body and Its Care. American Library Association, 1929. Reading with a Purpose Series.

FORD, H. J. Representative Government. Henry Holt, 1924.

Three hundred pages of fundamentals by an able journalist who became Professor of Politics at Princeton through Woodrow Wilson's appreciation of his book on "The Rise and Growth of American Politics."

FOWLER, HENRY W. Concise Oxford Dictionary of Current English. Oxford University Press, 1926.

A large amount of information in very little space.

HOWELL, A. C. Handbook of English in Engineering Usage. Wiley, 1930.

Clearly written book for practicing engineers. Promotes proficiency in making up reports, letters, and technical articles, and is "a shining example of the principles enunciated."

KILPATRICK, W. H., edited by. The Educational Frontier. Century, 1933.

A description of a definite program for remedying the confusion existing today in purpose and curriculum of American education.

MARTIN, EVERETT DEAN. Civilizing Ourselves. Norton, 1932.

SPENCER, HERBERT. Education—Intellectual, Moral, and Physical. Appleton, 1914.

Argument for rational scientific education of the body, natural and reasonable moral training, and self activity and interest in intellectual training.

WRIGHT, R. V. The Engineer's Duty as a Citizen. Newark (N. J.). College of Engineering Press, 1935.

A series of lectures by a former president of the A. S. M. E. on the citizenship responsibilities of an engineer and indicating how he may participate in political affairs.

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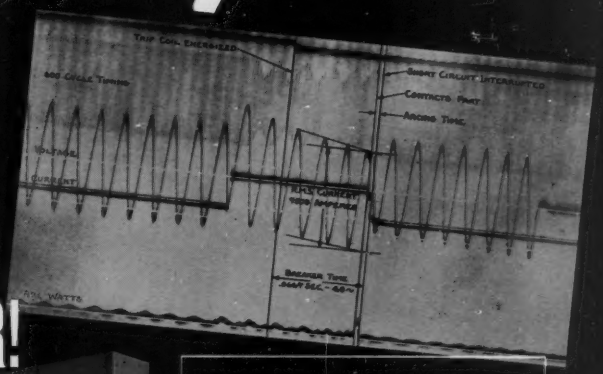

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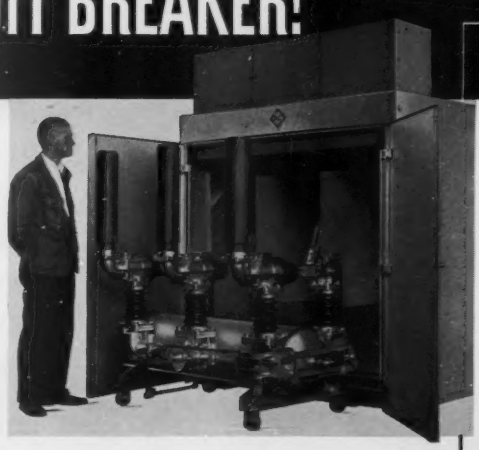

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